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10 Breakthrough Technologies 2014

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They say that tradition is what makes a luxury sedan, but is that truly the case? Or can luxury simply be defined by the way something looks? The way it feels? The way it makes you feel? Perhaps it's the way it makes others feel about you? While some will cling to the notion that heritage is what makes a luxury sedan, the open-minded will form an opinion of their own.

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From the Editor

GUIDO VITTI

IN THIS ISSUE OF THE MAGAZINE, BRIAN Bergstein, *MIT Technology Review*'s deputy editor, interviewed Sarah Lewis, a curator, about the "accomplishments that come from seemingly improbable circumstances and the connections between art and science" (see "Q&A: Sarah Lewis," page 22). Asked about Samuel Morse, who invented the telegraph after years of struggling as a painter, Lewis says:

"Few people recognize that when they're moved by a work of art, they're moved by an artist's ability to solve a problem that is often a long-standing, timeless one. For Cézanne, it was how to realize nature in paint. He didn't sign 90 percent of his paintings, because he didn't feel he had yet solved the problem ... All these different works are solutions to problems. For some people, there's no differentiation between finding something new in paint and finding something technologically."

Lewis also talks about how attempts to solve problems in art and technology often risk failure—not merely the failure that Silicon Valley cheers (where venture capitalists decline to continue funding a startup, and the entrepreneur turns to another venture) but deep failure, where "your entire life" is a loss.

This desire to solve problems, which is common to all real artists and true innovators, recalls the career of James Turrell, who "for almost half a century ... has been making innovative art out of the most fundamental elements: light, space, and time." In "Enlightened Spaces" on page 76, the art critic Martin Gayford describes Turrell's masterpiece, at an extinct volcano called Roden Crater: "in sheer scale, the most ambitious artwork of the late 20th and early 21st centuries." It is "still unfinished after 40 years in the making."

The artwork, in the Painted Desert of Arizona northeast of Flagstaff, "features a huge circular opening to the sky, circumscribed by the rim of the crater itself, and creates the illusion (from ... inside the crater) of a heavenly dome above," Gayford writes. "Below the surface are many openings and chambers that are configured with particular celestial sights." Tunnels at Roden Crater function as camerae obscurae, projecting onto walls images of the sun at the summer and winter solstices, or of the moon every 18.61 years.

The installation at Roden Crater may never be finished. As an attempt to solve the problem of how (in Turrell's words) he could create "spaces that engaged celestial events in light," the monumental artwork may be a lifetime's failure. On the project's website, Turrell has posted a message: "I ask for your patience, realize that no one has been more patient than I have."

Every year, we highlight 10 technologies that we believe will have a great impact. (See "10 Breakthrough Technologies," page 25.) This year, each breakthrough was the solution to a long-standing problem, and in a few cases it followed decades of frustration. Whether the problem was creating machines that have the balance and agility to walk and run across rough and uneven terrain (see "Agile Robots," page 30) or designing virtual-reality goggles finally good enough and cheap enough to be widely used (see "Oculus Rift," page 50), the solutions demanded artistic creativity as well as a willingness to suffer failure. Technologists tend to remember those innovators who succeeded in solving problems (and we celebrate them in these pages); yet more heroic are those who contributed without recognition to the incremental improvements or necessary but unsuccessful experiments that led ineluctably to the breakthrough itself.

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THE SPARK OF INNOVATION

R&D FUNDING PROGRAM

The National Reconnaissance Office Director's Innovation Initiative (DII) Program funds cutting-edge scientific research in a high-risk, high-payoff environment to discover innovative concepts and creative ideas that transform overhead intelligence capabilities and systems for future national security intelligence needs. The program seeks out the brightest minds and breakthrough technologies from industry, academia, national laboratories, and U.S. government agencies.

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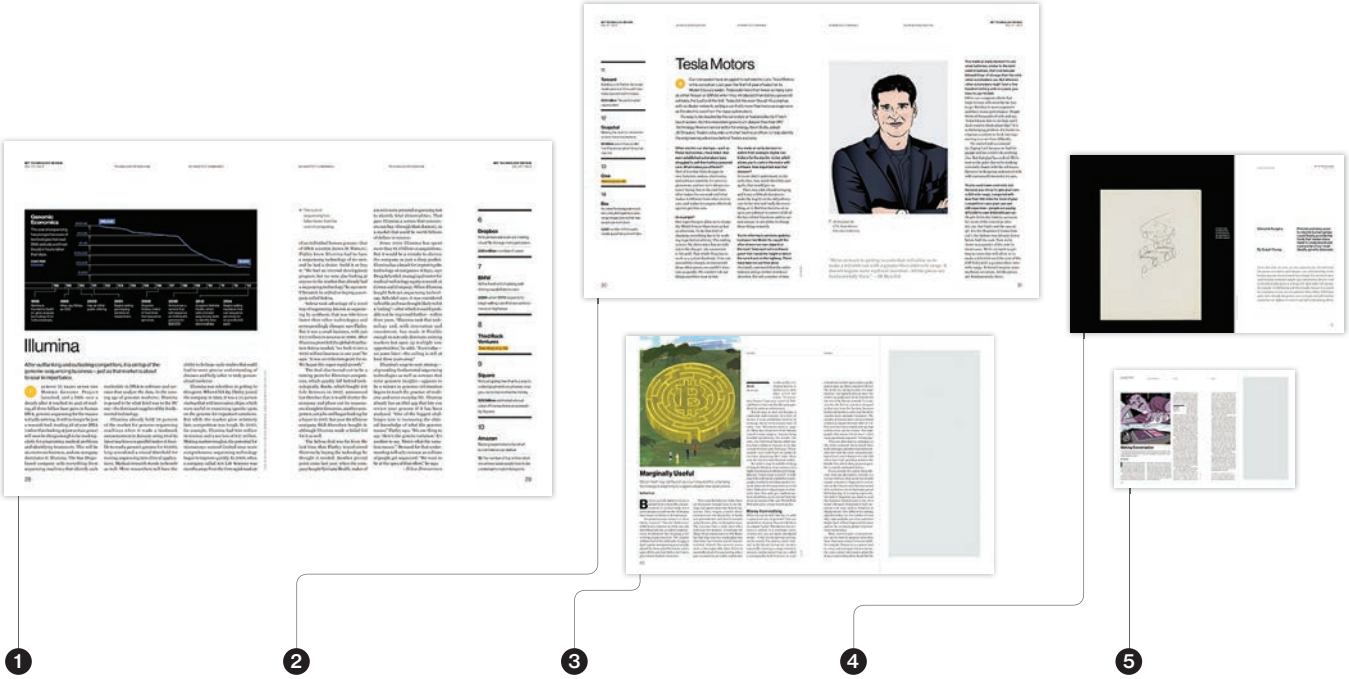
MIT Technology Review Volume 117, Number 2



1 50 Smartest Companies: Illumina

This is a convenient synopsis of Illumina's journey, but it does rather overstate their research effect so far. One run on a small Illumina machine kicks out about 40 gigs of data. Now run that three days a week and think about the server farms that will have to be built to support all of this. It's definitely progress but it's not all roses and champagne quite yet. **—syb**

2 50 Smartest Companies: Tesla

I still think electric cars are either a dead end or destined to remain boutique. Fuel cells, once we can extract hydrogen in an environmentally neutral fashion (as opposed to from natural gas), will be superior. Heck, even now a high-efficiency hybrid can put up numbers close to an electric. The evolution of the automobile is beginning to resemble the evolution of the locomotive, and diesel electrics pretty much won that one. **—Stan U.**

3 Marginally Useful

Paul Ford claims a "small number of humans have chosen to believe" in Bitcoin's legitimacy. Not true: they simply found out they don't need a third party to pay somebody. **—Hellwiss**

@Hellwiss Right on! "Small number" isn't even accurate. There are millions of people who own cryptocurrency. **—timrpeterson**

@Hellwiss They also found out that their fantasy money may be there at an exchange one day and not there the next. Not to mention that its value can be half of what it was in a couple of weeks, or double. **—simonts**

4 Genome Surgery

The advances in genomics over the past decade have been incredible. I hope the field maintains its momentum, but I also hope people are discussing how to minimize the threat of improper use of these tools.

—sgillila777

Every time I read an article about such work, I hope it's an early sign of breakthroughs at the clinical level for people like my developmentally disabled son. Unfortunately, as the years pass I continue to find an enormous gulf between reports of what might be coming and what is actually available.

—fatherspledge

5 Making Conversation

The true horror is not that people may be "emoting into the void," as Greg Egan concludes about the movie *Her,* but that behind the beguiling and entrancing voice is a malevolent and very human set of interests, be they corporate or political. *Her* completely dodges this angle, but the fact is that everything about Twombly could have been spied upon by the makers of the OS that Samantha arose from. Everything she sees and experiences could be mined to enhance the power of her creators.

—Rigatoni

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Glass Means Business

SIMSON GARFINKEL, IN HIS REVIEW OF Google Glass ("Glass Darkly," March/April), says he fears Glass is too "creepy" to be widely accepted. But he's missing the point.

Think of the first time you saw someone using a tablet. That person probably wasn't a teenager at the mall. More likely, it was a delivery person, or maybe an operations professional at the airport. That same story is playing out now with Glass.

Our society will gradually work out cultural norms regarding Glass usage in everyday environments, and the angry tweets will fade.

Glass is especially useful for people who perform urgent work, who work on the go, who use their hands, or who are burdened by requirements for lots of documentation. That's why startups focused on Glass are finding traction in areas such as law enforcement, manufacturing, energy—and health care, which is the focus of my own startup.

Many of the criticisms voiced by Garfinkel melt away in a professional setting. Far from being unwieldy, Glass can actually free physicians from laptops loaded up with electronic-health-record software. As with tablets, the hardware and the software need to evolve—and the price needs to drop—before we'll see anything like mass adoption. Google knows this, and is no doubt investing in next-generation versions of the device that will tackle the well-trodden shortcomings pointed out by Garfinkel.

Our society will gradually work out cultural norms regarding Glass usage in everyday environments, and the angry tweets will fade. Don't forget, we had to work through these issues with mobile phones, too. As more people use Glass, the developers who are now "Glassifying" existing smartphone apps just might be seen as prescient.

Ian Shakil
Founder and CEO, Augmedix
San Francisco

The Rights of Mann

I COULDN'T DISAGREE MORE WITH STEVE Mann's plea for new legislation to protect the rights of those who wear, and use, wearable computers in public spaces ("Glass Allowed," March/April). He acknowledges the need to balance the rights of Glass wearers with the right to privacy among those who don't wear Glass, but he fails to understand that Glass can and will be hacked. People will find ways to manipulate Glass so that observers won't be able to tell if they're being recorded. This is not a commentary on Glass wearers—it's just human nature. In the same issue, Simson Garfinkel makes several salient observations. Among others, he notes that application developers are already finding ways to skirt Google's user rules, which include banning the use of its glasses for facial recognition or voice prints.

Wearable glasses may have huge benefits for a few to overcome disabilities. They might significantly benefit some people in their work. But for many they will be mere toys, the latest gadget. Is the convenience of a few Glass users worth sacrificing the rights of the many who will never use them?

John K. Gamman
Santa Cruz, California

Correction: "Storing the Sun" (Demo, March/April) incorrectly stated that 60 pallets of batteries from Aquion Energy would be needed to serve a village of 200 people. Aquion estimates that only 20 pallets would be required.

Views

David Lazer

Lorrie Faith Cranor

Nathan Myhrvold

COMPUTING

Mistaken Analysis

It's too easy to be led astray by the lure of big data, says David Lazer.

GOOGLE FLU TRENDS HAS LONG BEEN the go-to example for anyone asserting the revolutionary potential of big data. Since 2008 the company has claimed it could use counts of flu-related Web searches to forecast flu outbreaks weeks ahead of data from the Centers for Disease Control and Prevention.

Unfortunately, this turned out to be what I call big-data hubris. Colleagues and I recently showed that Google's tool has drifted further and further from accurately predicting CDC data over time. Among the underlying problems was that Google assumed a constant relationship between flu-related searches and flu prevalence, even as the search technology changed and people began using it in different ways.

That failure is the big-data era's equivalent of the *Chicago Tribune*'s "Dewey Defeats Truman" headline in 1948. After public-opinion surveys erroneously predicted Dewey's victory, the *New York Times* declared polling "unable to compute statistically the unpredictable and unfathomable nuances of human character." Yet 64 years later, polling is used widely and successfully. In aggregate it predicted the overall margin of the latest presidential election within tenths of a percentage point, as well as the outcome in all 50 states. Surveys remain the bread and butter of social-science research.

That turnaround happened in part thanks to soul-searching by humbled survey companies that led to the development of rigorous, reliable sampling and polling methods. Similar soul-searching is necessary for big data.

One lesson we should draw is that methods and data should be more open. If Google Flu Trends had been more transparent, researchers would have competed to extract a cleaner signal from the raw data. Instead, the tool was not recalibrated for years. A corollary is that we need ways for scholars to build on and use proprietary data while respecting the rights of the data's owners and the privacy of people represented.

We also need to build multidisciplinary teams around big-data tools. Many problems with Google Flu Trends are of a type well known to generations of social scientists. Unfortunately, big-data analysis is rare in leading social-science journals, and basic social-science research concepts are missing from most big-data research.

Big data is surely being hyped (see "The Limits of Social Engineering," page 86). Yet the essential promise of Google Flu Trends is fundamentally correct. We now have access to detailed data about individual movements, behaviors, and communication. Used correctly, this information could be the starting point for a new "societal science" that can illuminate and do good for the world.

David Lazer is a joint professor in political science and computer science at Northeastern University.

INTERNET

Self-Defense

It is difficult to protect your privacy even if you know how, says Lorrie Faith Cranor.

I AM A PRIVACY RESEARCHER WITH A confession to make. I'm not any better at protecting my privacy than you are. For 17 years I've been interviewing people about their privacy concerns, studying how companies collect and use personal

SAM KERR

information, and researching the latest surveillance techniques. I attend privacy conferences, read privacy books, and have written a couple myself. But when friends ask me how to protect their privacy, I don't have much to tell them. Like most people, I want more privacy but find it difficult to get: few products allow us such control (see "Ultraprivate Smartphones," page 34).

My Web browsers are cluttered with privacy tools I've installed. One, Ghostery, tells me how many companies are trying to track me on every site I visit (it reports nine on technologyreview.com). I've set up Ghostery to block all tracking, but I often turn it off because that stops some e-commerce sites from working. As a result, several pairs of shoes and a sweater are currently following me around the Internet. I am concerned about trackers learning more about me, but taking steps to prevent that would be inconvenient.

A few years ago my students and I conducted a study where we watched dozens of people use privacy tools. Participants struggled with them, and some who believed they had protected their privacy actually failed to do so. In another study we surveyed over a thousand people about the AdChoices icon that the ad industry uses to notify people about behavioral advertising. Most respondents were unfamiliar with it and afraid to click on it.

As we've learned more about U.S. surveillance capabilities, encrypted e-mail seems to make sense. Yet having used encryption tools off and on for over two decades, I still find e-mail encryption too cumbersome to bother with.

I can maintain some privacy through self-censorship: I think carefully before I post to social networks, refrain from transmitting some types of information via e-mail, and avoid some websites altogether. But I regularly expose my kids' photos to Facebook and my Web browsing to hundreds of tracking companies. I hope they will all keep this information to themselves, but I know they will not.

Research suggests that people really do care about privacy and are even willing to pay a little to protect it. But there isn't one easy thing they can do that will make much difference, and doing many different things is tricky even for experts. If we want to make privacy practical for everyone, we need privacy tools that are built seamlessly into the software and services we use.

Lorrie Faith Cranor is director of the CyLab Usable Privacy and Security Laboratory at Carnegie Mellon University.

ENERGY

Irrational Fears

We should think sensibly about nuclear energy's risks, says Nathan Myhrvold.

CLIMATE SCIENTISTS HAVE CONSISTENTLY demonstrated how important it will be to drastically reduce human-generated carbon emissions. Yet almost no progress has been made. Hydroelectric power is reliable and cheap, but there aren't enough suitable sites to satisfy our energy demands. Wind and solar energy don't provide consistent output, and battery technology would have to improve significantly to solve that problem. Today, renewables are just an expensive supplement to an electricity system based on coal and natural gas.

There is one source of carbon-emission-free energy that is cheap, reliable, and proven to work on a large scale: nuclear power (see "Nuclear Options," page 16). It often gets a bad rap because of perceived safety problems. In reality, it has become a sort of litmus test for societal rationality. People have a hard time estimating some kinds of risks. For example, they fret about the safety of flying but show little concern for driving, despite statistics showing that cars kill vastly more people than planes do.

Similarly, incidents like Chernobyl, Three Mile Island, and Fukushima capture our attention but mislead us as to the risks. Statistics from the World Health Organization and other sources suggest that coal kills about 4,000 times as many people per unit of energy produced as nuclear power does. That counts only here-and-now effects such as air pollution and ignores long-term damage due to climate change.

A close look at Fukushima is instructive. The tsunami killed about 16,000 people; radiation from the reactor has killed none. In fact, the nuclear accident was entirely preventable. The plant has a 40-year-old design lacking modern safety features. Worse, it was designed to withstand only 5.7-meter tsunamis in a region known to endure waves of 20 meters or more. Numerous design decisions proved disastrous. For example, the backup generators for the plant's safety systems were located near the sea, at the lowest point in the complex. Cooling ponds for spent nuclear fuel were located on the roof, making them vulnerable to leaks when the building was damaged.

The real lesson of Fukushima is that we should build modern nuclear plants and show some common sense about where they are located. Building out coal kills far more people, and continuing to emit carbon dioxide causes planetwide risks that dwarf those associated with radiation leaks. Even Japan is coming around to this point of view, after a sharp rise in both energy costs and carbon emissions. Mature societies must be driven by facts, not our irrational fears.

Nathan Myhrvold is a cofounder of Intellectual Ventures, whose subsidiary TerraPower is designing a novel nuclear reactor.

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Upfront

EMMANUEL POLANCO

Augmented Reality Gets to Work

The technology hasn't yet lived up to its promise, but it could catch on in situations where it makes employees more efficient.

By Rachel Metz

For Thomas Caudell, it started with a desire to make building airplanes easier. It was 1990, and Caudell, then a scientist at Boeing, was trying to figure out how to help workers assembling long bundles of wires for the new 777 jetliner.

To do the wiring correctly, workers had to continually glance between an instruction sheet and the assembly, which complicated an already tricky job. Caudell and his colleague David Mizell had an idea: what if they could give the assembly workers a see-through display that would show where the wires should go? The 777 was the first jetliner to be digitally modeled in full before it was assembled, so there were already computerized images of its components.

Caudell and Mizell built a system that the workers could wear on their heads. Like other early attempts to overlay the real world with bits of the virtual, it failed to catch on. Caudell says that was largely

Upfront

QUOTED

"This isn't Fitbit for Granny."

— Satish Movva, CEO of CarePredict, which sells a band for seniors that tracks not just their activity levels but also their position.

because the head tracking wasn't responsive enough, and wearable computers were nowhere near as powerful as they are today. However, he did come up with a term for this new kind of digital vision: augmented reality.

In the decades since, augmented reality has crept toward acceptance. It's still far from commonplace, because handheld gadgets aren't that immersive and smart glasses are still pricey and awkward-looking. But fashion and price don't matter to companies eager for technologies that help their employees work more efficiently. The defense contractor Raytheon and the electronics maker Mitsubishi Electric, among other large companies, have been trying augmented reality in the workplace and out in the field. "Some companies are thinking, 'Look, this is interesting enough—we'll take some bets on it, we believe there's a good chance,'" says Soulaiman Itani, founder and CEO of Atheer Labs, which makes 3-D virtual-reality software and glasses. The California-based company is working on pilot tests of augmented reality in hospitals, on construction sites, and in factories.

An augmented-reality software startup called Daqri, based in Los Angeles, is also getting companies to explore the technology. Like Atheer, Daqri sees head-worn displays as the way we will eventually use the technology, but for now much of its focus is on smartphone and tablet displays.

Founder and CEO Brian Mullins demonstrates his startup's technology with a piece of paper featuring a basic diagram of the human heart, an iPad, and a Daqri app. The app makes the heart seem to levitate atop the paper, pulsing slightly as cartoon blood pumps through it. Daqri's software tracks the iPad's movement, making it possible to see the heart from different angles. It isn't yet something that would be useful on a factory floor, but several companies, including the defense contractor Raytheon, are trying it out.

Mitsubishi is testing whether technicians benefit from a 3-D view of an air conditioner's parts.

Raytheon has used a 3-D model made by Daqri to show progress on a cylindrical signal-jamming device that will fit on the wings of Navy fighter planes. Modeling the device with augmented reality allows viewers to walk around it, pop open doors, explore the insides, and highlight various subsystems.

Augmented reality might also make things easier for workers who are away from the office or the factory. Mitsubishi Electric is using software from augmented-reality software company Metaio on Epson's Moverio smart glasses to test whether service technicians benefit from a three-dimensional overlay that identifies the components of the company's most popular residential air conditioner.

Tobias Hollerer, a professor at the University of California, Santa Barbara, who studies augmented reality, says getting people to accept the technology depends on factors that may not have improved as much as display and tracking technology have—namely, techniques for controlling the system, be it with gestures, voice, or something else entirely.

"Obviously there's a lag in deploying these technologies from when they became possible to when they became robust enough to actually be deployed in work flows," he says. "But I think there is enough of a benefit in augmented reality to make that leap."

Already, the technology is moving into the industry Caudell was hoping to augment back in the '90s. Some aircraft workers are using the Moverio glasses to simplify the process of mounting components within airplane engines.

TO MARKET

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SpaceX

PRICE:
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AVAILABILITY:
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SpaceX is testing a new kind of reusable booster rocket. After delivering cargo, the first stage of the company's Falcon 9 rocket fires its engines for the second time, reëntering the atmosphere in controlled flight before returning safely to the ground. The booster could offer much cheaper access to space. "Reusability has been the holy grail of the launch industry for decades," says Jeff Foust, an analyst at Fultron. But even without reusable rockets, SpaceX has shaken up the $190-billion-a-year satellite launch market with lower launch costs than its competitors. French rocket company Arianespace has indicated that it may ask for an increase in government subsidies to remain competitive.

COURTESY OF SPACE X (ROCKET); COURTESY OF SATISH MOVVA

An array of sensors is embedded in a material designed to fit a beating heart perfectly.

COURTESY OF JOHN ROGERS

Heart Implants, 3-D-Printed to Order

Tailor-made medical devices could give a more detailed picture of cardiac health and prevent problems.

By Katherine Bourzac

Somewhat poetically, everyone's heart is a slightly different size and shape. And yet cardiac implants—devices like pacemakers and defibrillators—are basically one size fits all.

Researchers have now demonstrated a new kind of personalized heart sensor as part of an effort to change that. They used images of animals' hearts to create models of the organ using a 3-D printer and then built stretchy electronics on top of those models. The material can be peeled off the model and wrapped around the real heart for a perfect fit. The research team has also integrated an unprecedented number of components into these devices, demonstrating stretchy arrays of sensors, oxygenation detectors, strain gauges, electrodes, and thermometers made to wrap perfectly around a particular heart.

One device badly in need of improvement is the implanted defibrillator, which is attached to a misfiring heart and uses readings from one or two electrodes to determine whether to restore a normal heartbeat by applying an electric shock. With information from just one or two points, the electronics in these systems can make the wrong decision, giving the patient a painful, unnecessary shock. "The next step is a device with multiple sensors, and not just more electrical sensors," says Igor Efimov, a cardiac physiologist and bioengineer at Washington University in St. Louis, who helped develop the new sensor. Measuring acidic conditions, for example, could offer an early sign of a blocked coronary artery. Meanwhile, light-emitting diodes and light sensors could provide information about heart-tissue health by identifying areas with poorly oxygenated blood, which is less transparent to light. Light sensors might even help detect a heart attack, since the enzyme NADH, which accumulates during heart attacks, is naturally fluorescent.

Efimov is collaborating on smarter heart implants with John Rogers, a materials scientist at the University of Illinois at Urbana-Champaign. The collaboration builds on Rogers's work with his company MC10 to integrate different sensors into flexible, biocompatible materials. The researchers used optical images of rabbits' hearts to demonstrate the concept. To make devices for patients, they would use CT or MRI scans of each person's heart, as they explained in a paper published in *Nature Communications* in March.

Nicholas Peters, head of cardiac electrophysiology at Imperial College London, says the equipment could precisely measure multiple heart functions at once—something that's not been possible before. "This level of precision of co-localized electrical and mechanical functional measurement has long been sought," says Peters. "This approach immediately raises the realistic possibility of clinical application in human heart disease."

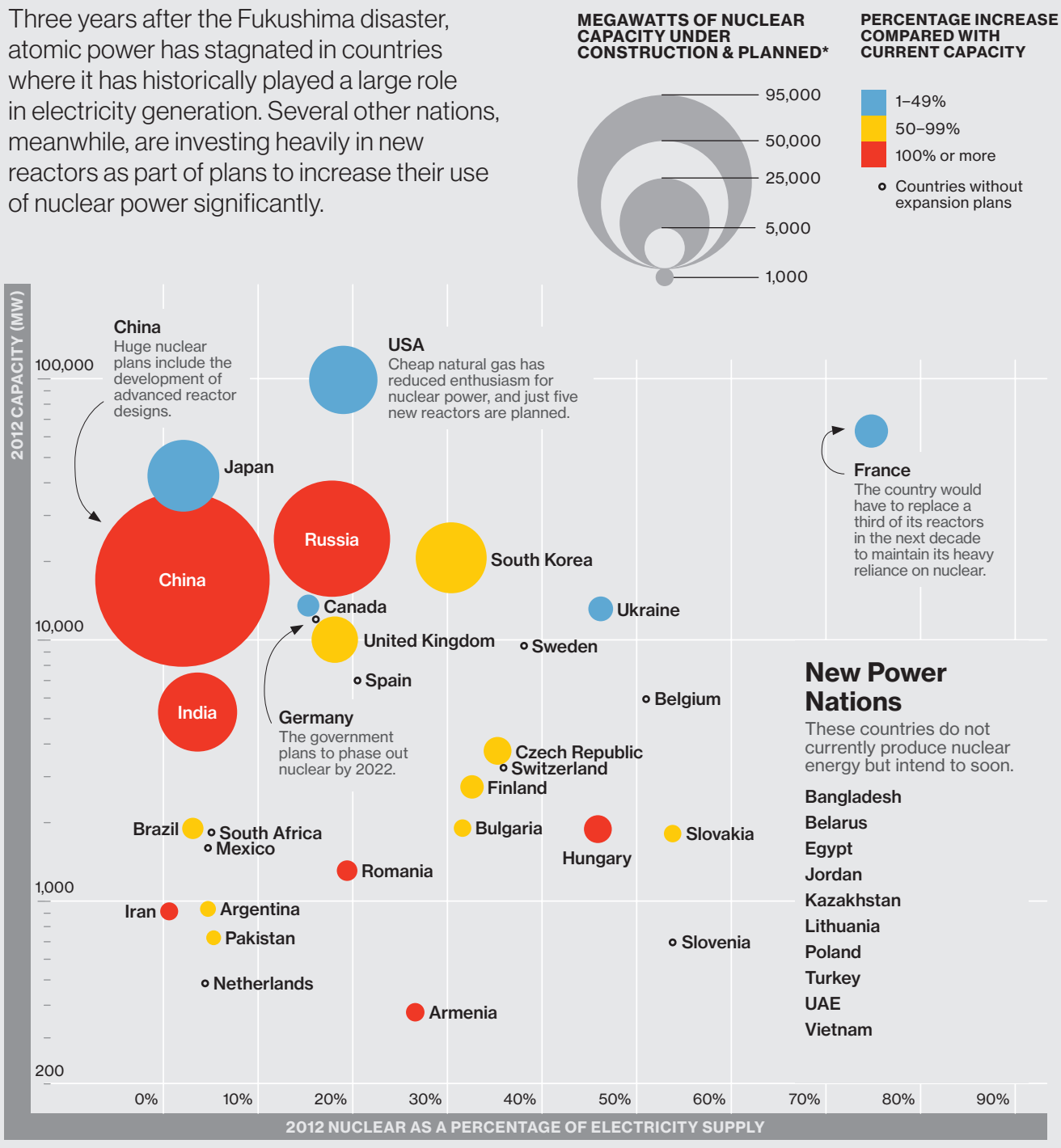
Implanted devices such as pacemakers and defibrillators are badly in need of improvement.

Devices made through custom manufacturing would be more expensive than mass-produced medical devices, but for these kinds of life-or-death applications, the market is likely to bear the cost.

Upfront

Nuclear Options

Three years after the Fukushima disaster, atomic power has stagnated in countries where it has historically played a large role in electricity generation. Several other nations, meanwhile, are investing heavily in new reactors as part of plans to increase their use of nuclear power significantly.



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*REFERS TO NUCLEAR PLANTS THAT THE WORLD NUCLEAR ASSOCIATION EXPECTS TO BE OPERATIONAL IN 8–10 YEARS

QUOTED

"They are setting fire to the future of the Internet. And the people in the room now, you guys, are the firefighters."

—Edward Snowden, addressing SXSW via videoconference, on government surveillance.

Cheaper Cancer Gene Tests, by the Drop

A single-molecule test requires much less DNA to identify cancer-causing mutations.

By Susan Young Rojahn

The DNA of cancer cells provides intriguing clues about how the disease might be defeated. Unfortunately for cancer patients, however, getting the DNA for analysis often requires invasive surgical biopsies.

But researchers are making progress on a cost-effective method for avoiding that problem. They've developed a way to identify the cancer-causing mutations in cells even when only small amounts of DNA are available.

Developed by RainDance Technologies, a maker of genomic tools based in Billerica, Massachusetts, the technology may one day enable doctors to perform a variety of molecular tests on small numbers of cells harvested from solid tumors or even found floating in blood samples.

Medical researchers and physicians are increasingly testing the DNA of tumors to follow the progression of a cancer, identify molecular targets for new drugs, and determine which treatments will work best for specific patients. But many tumor samples aren't suitable for sequencing because they don't contain enough DNA or because the DNA they do contain is damaged.

RainDance's test gets around that problem because only a tiny amount of tumor DNA is needed. It uses microscopic droplets of liquid in place of the small plastic tubes where DNA-manipulating reactions normally occur. Each droplet is around eight picoliters in volume—about one millionth of teaspoon. When the droplets are generated on a RainDance machine, they contain the components needed to amplify a known cancer gene. Researchers can then add a patient's DNA to the droplets, and reactions that duplicate the DNA occur inside them.

After amplifying the DNA in a sample, researchers can either sequence the genes using standard equipment or look for the presence of cancer genes using a machine made by RainDance itself.

The company was founded in 2004 to commercialize a system that chief technology officer Darren Link developed as a postdoctoral researcher at Harvard. For now, the technology is offered only to researchers and is not available for clinical use.

But research applications alone are intriguing. For one, the technology makes it possible to sequence samples that have been treated with chemical fixatives for preservation—a standard practice, says Roopom Banerjee, RainDance's CEO and a former clinical scientist at the Dana-Farber Cancer Institute in Boston. The fixatives break down DNA, so most DNA-sequencing methods can't be used on these samples. RainDance's technology, however, can make use of even a single intact copy of a gene, so now the more than 100 million preserved cancer samples stored in biobanks around the world could be used in cancer research, Banerjee says.

TO MARKET

Wearable Apps

Android Wear SDK

COMPANY:
Google

PRICE:
Free

AVAILABILITY:
Now

Motorola's Moto 360 smart watch is sleek and round, evoking the style of a classic wristwatch. But beneath the slick design lies even slicker software, called Android Wear, that allows powerful wearable apps to be created using simple tweaks to existing Android apps. Some developers and designers are already prototyping the first wearable apps based on it. Other smart watches use new operating systems, forcing prospective developers to learn to code for a new platform. Cecilia Abadie, a developer at 33Labs in Los Angeles, who is building a fitness app using Google's new software, says: "Android Wear has better chances of winning the next big battle of wearables against Apple."

COURTESY OF MOTOROLA; COURTESY OF WIKIMEDIA COMMONS (SNOWDEN).

Upfront

billion
The number of cell-phone subscriptions worldwide

Apps for the Dashboard Face Strict New Rules of the Road

New cars will soon come with high-bandwidth connections and app stores.

By David Talbot

Many buyers of new cars will soon get a novel feature: in-car Internet connections with speeds similar to those on the fastest smartphones. Backseat passengers could get streaming movies and fast Wi-Fi connections to smart watches and tablets. For drivers, high-resolution navigation maps would load quickly, and high-fidelity audio could stream from Internet radio services.

The first U.S. automotive model with the fast wireless connection—known as 4G LTE, a technology that's around 10 times faster than 3G connections—is the 2015 Audi A3, which is already available for a starting price of $29,900. Data plans will cost extra—an average of around $16 a month.

GM expects to sell 4G-equipped 2015 Chevrolets and other models in June. Other carmakers, including Ford and Toyota, are following suit in the U.S. and worldwide, using partnerships with wireless carriers to deliver the connectivity.

Apps in cars will have a captive audience: drivers often find themselves behind the wheel for an hour or two a day.

By providing dashboard apps, carmakers see an opportunity for product differentiation and steady revenue streams. They also suggest that connectivity can lead to new safety features and that using these onboard services will be safer than furtively glancing at smartphones.

But when drivers browse the GM AppShop, they shouldn't expect what they get on an iPhone or a Galaxy phone. GM expects to provide just 10 apps initially, most of them mapping, news, and radio services. That's partly because the automaker's screening process is so strict, says Greg Ross, director of product strategy and infotainment for GM vehicles. "They go through rigorous safety and security standards," he says. "And since it's pulling data from the car, it's locked down."

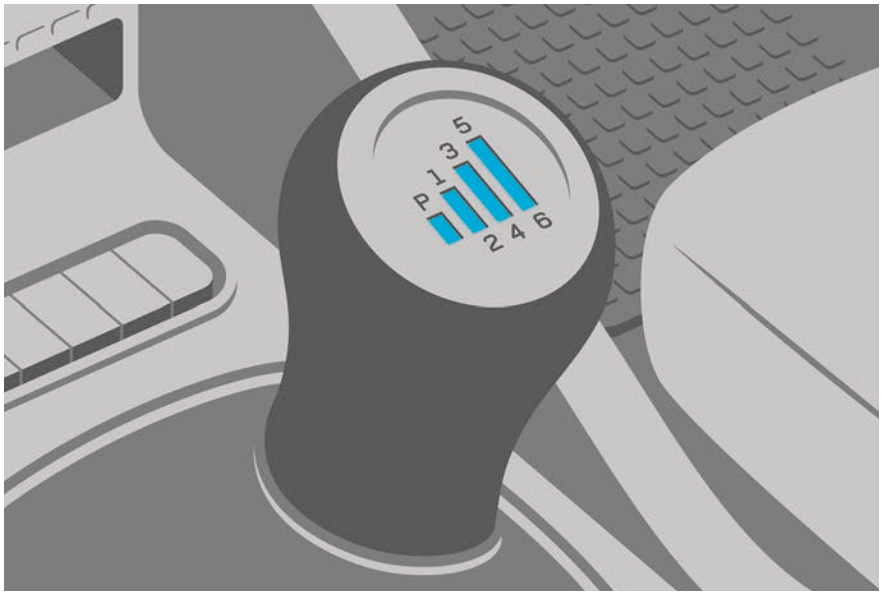
As a result, the technology and interface need to be almost as simple as an analog radio knob, says Bruce Hopkins, cofounder of BT Software, based in San Diego. He is one of a very few developers whose apps will be available in GM cars.

Called Kaliki, BT Software's app provides audio readings of stories—done by humans, not text-to-speech software—pulled from mainstream publications such as *USA Today* and *TV Guide*, as well as podcasts from radio and TV stations. (Its advantage over the radio? "Radio has been around for the last eight decades, and you still can't pause it," he says.)

The apps know if you are driving; drivers will never be able to open a "terms and conditions" screen—or play a game, assuming games ever come—unless the vehicle's transmission is in "park."

Despite the hurdles, 4,000 developers have registered with GM's app store. Getting their apps included in a car could help them market versions that work on smartphones. And apps in cars command much more attention if they are among just a few that a driver can choose from for an hour or two every day.

In the longer term, apps will emerge that draw on data generated by the car, says GM's Ross. This could be useful for maintenance or driving efficiency, or to generate data for insurance discounts.



MATT CHASE; SOURCE: ITU

Software That Matches Faces Almost as Well as You Do

Facebook researchers take a big step with an AI technique known as deep learning.

By Tom Simonite

Asked whether two unfamiliar photos of faces show the same person, a human being will get it right 97.53 percent of the time. New software developed at Facebook scores 97.25 percent on the same challenge, regardless of variations in lighting or whether the person in the picture is facing the camera.

That's a significant advance over previous face-matching software, and it demonstrates the power of a new approach to artificial intelligence known as deep learning, which Facebook and its competitors have bet heavily on in the past year. Deep learning is an area of AI that uses networks of simulated neurons to learn to recognize patterns in large amounts of data. (For more on improvements in AI, see "Neuromorphic Chips," page 54.)

Facebook's new software, known as DeepFace, performs what researchers call facial verification (it recognizes that two images show the same face), not facial recognition (putting a name to a face). But some of the underlying techniques could be applied to the latter problem and might therefore improve Facebook's accuracy at suggesting whom users should tag in a newly uploaded photo.

Yaniv Taigman, a member the AI team that Facebook created last year to explore how deep learning might help the company, notes that the error rate has been reduced by more than a quarter relative to earlier software. "You normally don't see that sort of improvement," he says.

The deep-learning part of DeepFace consists of nine layers of simple simulated neurons, with more than 120 million connections between them. To train that network, Facebook's researchers tapped a tiny slice of data from their company's hoard of user images—four million photos of faces belonging to almost 4,000 people.

DeepFace virtually rotates faces to face front, correcting for even tiny differences. Image (1) is the original, (7) the corrected version.

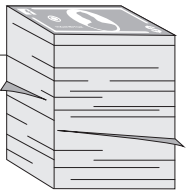
DeepFace processes images of faces in two steps. First, using a 3-D model of an "average" forward-looking face, it corrects the angle so that the person in the picture faces forward. Then the deep learning comes in, as a simulated neural network works out a numerical description of the reoriented face. If DeepFace comes up with similar enough descriptions for two different images, it decides they must show the same face. The final software was tested using a standard data set that researchers use to benchmark face-processing software and to measure human performance.

DeepFace remains purely a research project for now. Facebook has released a research paper on it, and the researchers will present the work at the IEEE Conference on Computer Vision and Pattern Recognition in June. "We are publishing our results to get feedback from the research community," says Taigman, who developed DeepFace with Facebook colleagues Ming Yang and Marc'Aurelio Ranzato and Tel Aviv University professor Lior Wolf.

Neeraj Kumar, a researcher at the University of Washington who has worked on face verification and recognition, says that Facebook's results show how feeding enough data into a large neural network can allow for significant improvements in machine learning. "I'd bet that a lot of the gain here comes from what deep learning generally provides: being able to leverage huge amounts of outside data in a much higher-capacity learning model," Kumar says. "Since they have access to lots of data of this form, they can successfully train a high-capacity model."

COURTESY OF FACEBOOK

Upfront



$42

The implied value of each WhatsApp user in Facebook's $19 billion deal to buy the company

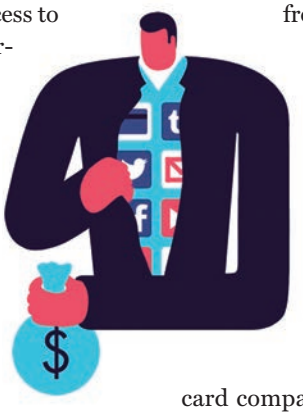
Sell Your Personal Data for $8 a Month

Would you let a startup track your social-media accounts and credit card transactions in exchange for cash?

By Tom Simonite

A startup called Datacoup is far from the only tech company hoping to get rich by selling insights mined from your personal data. But it may be the only one offering to give you money for that information.

Datacoup is running a beta trial in which people get $8 a month in return for access to a combination of their social-media accounts, such as Facebook and Twitter, and the feed of transactions from a credit or debit card. The New York City–based startup plans to make money by charging companies for access to trends found in that information, after personally identifying details have been removed.



Datacoup CEO and cofounder Matt Hogan says that almost 1,500 people have signed up during the beta trial and that within a few months the service will be open to everyone. The company also might offer people the option of sharing data from life-logging devices such as the Fitbit or from parts of their Web search history.

So far no advertisers have bought data from Datacoup, though Hogan says initial discussions have been encouraging.

Data on consumer behavior is hardly in short supply these days. It accumulates in the databases of social networks, ad networks, and wireless carriers, among others. But Hogan claims that few data providers can combine traces of a person's online activity with a record of spending activity. Validation for this idea—and competition for Datacoup—comes from Twitter and Facebook, both of which work with the data broker Datalogix to link people's social-media activity and the things they buy.

Alessandro Acquisti, who researches the behavioral economics of privacy at Carnegie Mellon University, notes that the idea of people trading their own data has been around for years but has never quite taken off. Author and computer scientist Jaron Lanier, for example, has argued for some time that it is fundamentally unjust if people don't see the profits made from their own information.

"Ethically, it makes sense that you know what is happening to your data and how an entity is using it and what the possible consequences are," says Acquisti. However, Datacoup doesn't really let people take control of their data, he says, since Twitter, Facebook, and the credit card companies it connects with retain that information and can continue to profit from it. "Measuring privacy tradeoffs is exceedingly hard," Acquisti says.

Hogan argues that encouraging people to think more about their data and its value could inspire them to demand more transparency from other companies that sell their personal information. "We're in the consumer's corner," he says.

3 QUESTIONS

Henry Tirri

Nokia's CTO on the group that remains after Microsoft's buyout of the cell-phone business.

On what areas will Nokia's Advanced Technologies business focus?

We are now talking about the idea of a programmable world. It reflects what will happen in your home, your connected car, with your wearable devices, and so on. Many of your smartphone apps already lose their value when they are not cloud-connected. The same thing will be true in the future for other everyday objects. A lot of our technological assets will help in the future evolution of this world.

What are some examples?

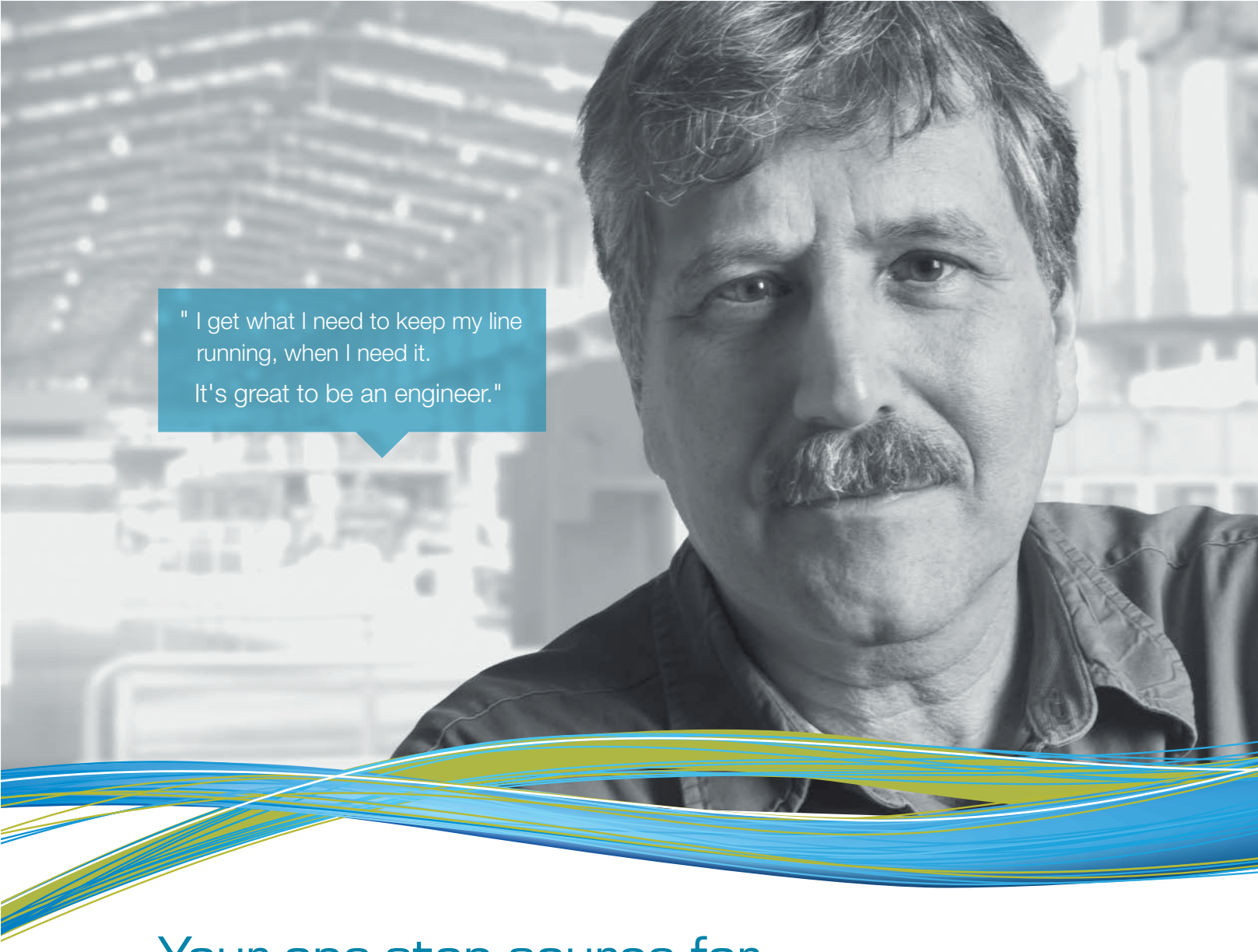
Any modern sensing app which is connected to a smartphone will be using Bluetooth LE, a low-powered technology for which much of the development was done in our labs. Other domains will be wearable sensors nanosensing various kinds of biological measurements that can be used for monitoring your health and wellness.

What about some new products?

We will explore new product areas, either to develop ourselves or potentially for technology licensing to others. We have an existing portfolio built from more than 50 billion euros of R&D investment over the last 20 years, as well as experience in building products. Beyond simply licensing IP, we expect to be developing technologies and products together with customers, in the way you see others such as Qualcomm or ARM doing.

—David Talbot

MAGOZ; DAVID TALBOT/MIT TECHNOLOGY REVIEW (TIRRI)



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Q+A

Sarah Lewis

The path to a great achievement—whether it is a technological innovation or a masterwork of art—is almost never direct. On the contrary, creative breakthroughs often come after wrenching failures. That idea animates *The Rise: Creativity, the Gift of Failure, and the Search for Mastery*, a book by Sarah Lewis, an art curator who is completing her PhD at Yale. Based on 150 interviews with artists and explorers as well as scientists and entrepreneurs, the book is neither a self-help manual nor a bundle of case studies. It's a meditation on accomplishments that come from seemingly improbable circumstances and the connections between art and science. Lewis spoke with *MIT Technology Review*'s deputy editor, Brian Bergstein.

Overcoming failure is the subject of bromides and commencement speeches. At FailCon events, startup founders swap tales of not succeeding. So what's different about your discussion of failure?
There are failures of very different magnitudes; I'm not even sure I would call some Silicon Valley failures failures. I think of failure as the gap between where you are and where you want to go. The larger it is, the more you call it failure, and the smaller it is, the more you call it having something to improve upon, or needing to pivot. You can have a series of failed entrepreneurial feats, and that feels very different from having your entire life feel like a failure.

I'm thinking [instead] of the importance of structures that let people go deep with their failure while letting it be an entrepreneurial endeavor if they like, or an innovative discovery.

What's an example?
Andre Geim, a physicist who is based at the University of Manchester, was not seen as someone who would ever win the Nobel Prize, because his experiments could be so outlandish. He won the IgNobel Award in 2000 for levitating a live frog with magnets—and then [won the Nobel] for isolating graphene 10 years later. He was dealing with failure: the psychological frustration that can come when people don't quite take you seriously was difficult for him to endure, required a kind of courage. And he did [the graphene work] through a process of Friday-night experiments: times where, in the laboratory, they felt free enough to fail, and therefore made these groundbreaking discoveries. He's a good example of what it means to allow the generative process of failure to help you, through these Friday-night experiments.

He was also doing something quite unusual, which is being a deliberate amateur: every five years or so he would go into another field [of physics] and work on other people's realms of expertise, go to all the conferences, and ask questions they didn't dare. It required that he get up to speed quickly in a new field but also, as he describes it, not read himself out of his own new ideas.

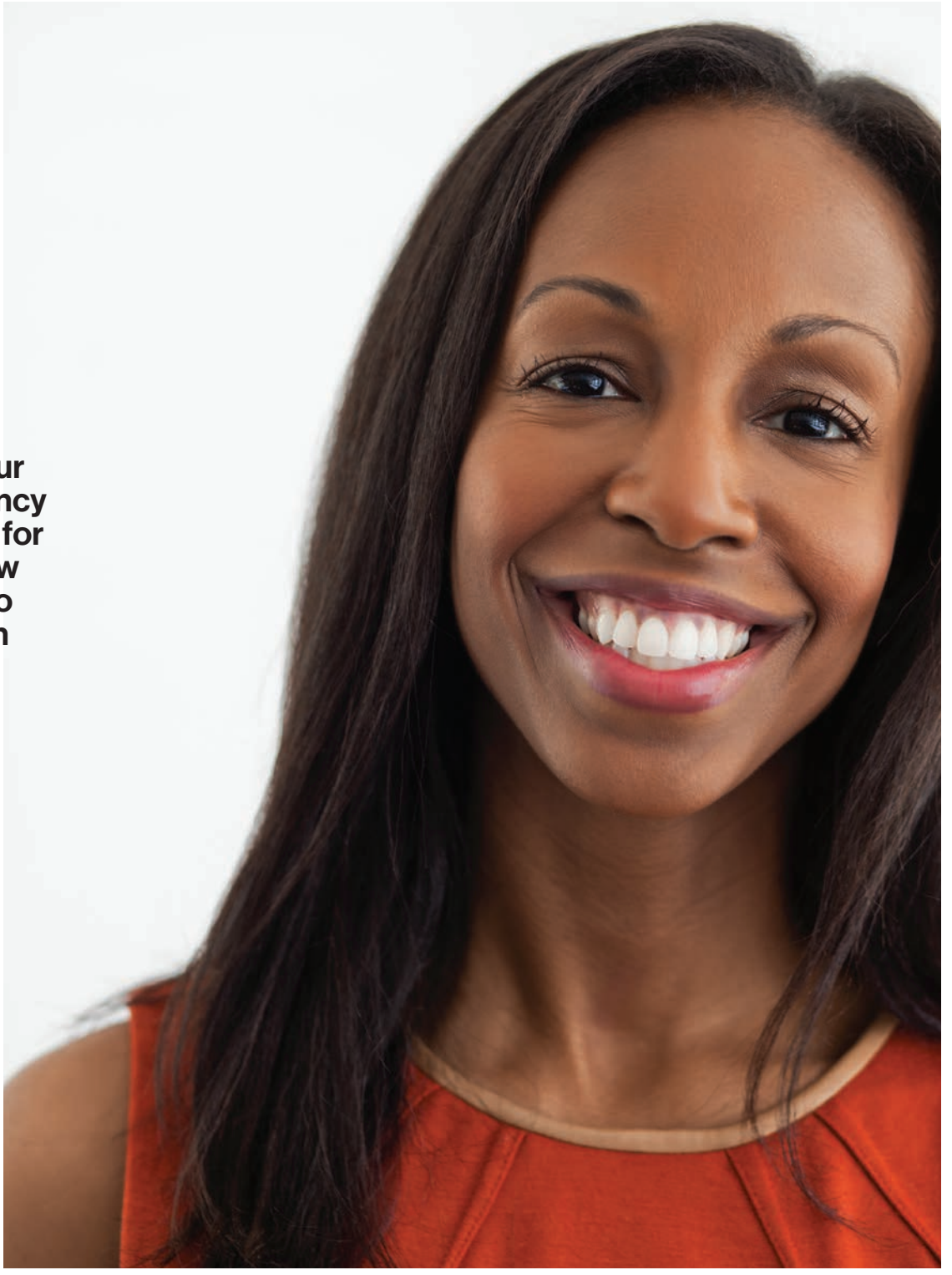
At least Geim moved between similar fields. You also write about Samuel Morse, who invented the telegraph after struggling as a painter—though you argue that his art and his invention were closely linked.
Invention, whether in paint or with wires, for him was really one and the same.

Few people recognize that when they're moved by a work of art, they're moved by an artist's ability to solve a problem that is often a long-standing, timeless one. For Cézanne, it was how to realize nature in paint. He didn't sign 90 percent of his paintings, because he didn't feel he had yet solved the problem. For Beethoven, it was how to innovate with sound that was new. All these different works are solutions to problems. For some people, there's no differentiation between finding something new in paint and finding something technologically.

In fact, you contend that art enhances the scientific quest.
I came across a great study by a physiologist, Robert Root-Bernstein of Michigan State University, who's found that there's a disproportionately high number of Nobel laureates in the sciences who have artistic avocations that don't drop away when their scientific work ramps up.

Why do you think that is?
What the arts allow us to do is develop the muscle required for discernment, and also strengthen our sense of agency to determine for ourselves how we're going to tackle a given problem. Especially when you're young, it's one of the few times there's no set path that someone can point you to go down to figure out the answer to a problem you're trying to solve. If you're in a math or science class and you're trying to learn different equations, there's an answer and you're trying to arrive at it. But if I'm drawing a beautiful plant—say I wanted to make the lines really thick. The teacher can't come over and say, "You know, the lines should be thinner." There's no *should*, really. Ultimately it's up to the person creating the work to determine what the path is, and that kind of agency is what's required for innovation.

“The arts ... strengthen our sense of agency to determine for ourselves how we’re going to tackle a given problem.”



Adam DeTour

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10 Breakthrough Technologies 2014

Technology news is full of incremental developments, but few of them are true milestones. Here we're citing 10 that are. These advances from the past year all solve thorny problems or create powerful new ways of using technology. They are breakthroughs that will matter for years to come.

—The Editors

Noma Bar

Genome Editing

The genomes of these twin infant macaques were modified with multiple mutations.

Breakthrough
The use of a genome-editing tool to create two monkeys with specific genetic mutations.

Why It Matters
The ability to modify targeted genes in primates is a valuable tool in the study of human diseases.

Key Players
- Yunnan Key Laboratory
- Jennifer Doudna, UC Berkeley
- Feng Zhang, MIT
- George Church, Harvard

COURTESY OF YUNNAN KEY LABORATORY OF PRIMATE BIOMEDICAL RESEARCH

The Experiment

The birth of twin monkeys whose DNA was altered with the new genome-editing tool CRISPR proves it's possible to create primates with precise genetic mutations.

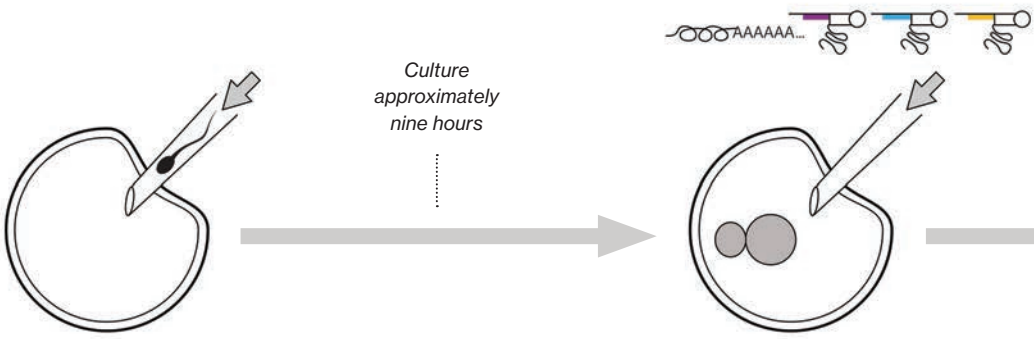
BY
Christina Larson

UNTIL RECENTLY, KUNMING, CAPITAL OF China's southwestern Yunnan province, was known mostly for its palm trees, its blue skies, its laid-back vibe, and a steady stream of foreign backpackers bound for nearby mountains and scenic gorges. But Kunming's reputation as a provincial backwater is rapidly changing. On a plot of land on the outskirts of the city—wilderness 10 years ago, and today home to a genomic research facility—scientists have performed a provocative experiment. They have created a pair of macaque monkeys with precise genetic mutations.

Last November, the female monkey twins, Mingming and Lingling, were born here on the sprawling research campus of Kunming Biomedical International and its affiliated Yunnan Key Laboratory of Primate Biomedical Research. The macaques had been conceived via in vitro fertilization. Then scientists used a new method of DNA engineering known as CRISPR to modify the fertilized eggs by editing three different genes, and they were implanted into a surrogate macaque mother. The twins' healthy birth marked the first time that CRISPR has been used to make targeted genetic modifications in primates—potentially heralding a new era of biomedicine in which complex diseases can be modeled and studied in monkeys.

CRISPR, which was developed by researchers at the University of California, Berkeley, Harvard, MIT, and elsewhere over the last several years, is already transforming how scientists think about genetic engineering, because it allows them to make changes to the genome precisely and relatively easily (see "Genome Surgery," March/April). The goal of the experiment at Kunming is to confirm that the technology can create primates with multiple mutations, explains Weizhi Ji, one of the architects of the experiment.

Ji began his career at the government-affiliated Kunming Institute of Zoology in 1982, focusing on primate reproduction. China was "a very poor country" back then, he recalls. "We did not have enough funding for research. We just did very simple work, such as studying how to improve primate nutrition." China's science ambitions have since changed



1 Sperm injection

Lab technicians inject a single sperm into an unfertilized egg.

2 Genome editing

The fertilized egg is injected with "guide" RNAs that target a specific gene, and a template for the DNA-cutting enzyme.

dramatically. The campus in Kunming boasts extensive housing for monkeys: 75 covered homes, sheltering more than 4,000 primates—many of them energetically swinging on hanging ladders and scampering up and down wire mesh walls. Sixty trained animal keepers in blue scrubs tend to them full time.

The lab where the experiment was performed includes microinjection systems, which are microscopes pointed at a petri dish and two precision needles, controlled by levers and dials. These are used both for injecting sperm into eggs and for the gene editing, which uses "guide" RNAs that direct a DNA-cutting enzyme to genes. When I visited, a young lab technician was intently focused on twisting dials to line up sperm with an egg. Injecting each sperm takes only a few seconds. About nine hours later, when an embryo is still in the one-cell stage, a technician will use the same machine to inject it with the CRISPR molecular components; again, the procedure takes just a few seconds.

During my visit in late February, the twin macaques were still only a few months old and lived in incubators, monitored closely by lab staff. Indeed, Ji and his coworkers plan to continue to closely watch the monkeys to detect any consequences of the pioneering genetic modifications.

The Impact

The ability to create primates with intentional mutations could provide powerful new ways to study complex and genetically baffling brain disorders.

BY

Amanda Schaffer

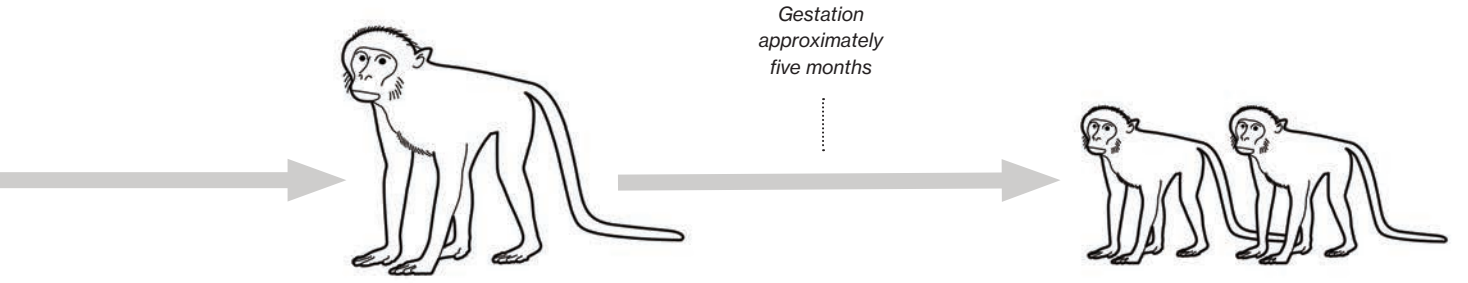
The new genome-editing tool called CRISPR, which researchers in China used to genetically modify monkeys, is a precise and relatively easy way to alter DNA at specific locations on chromosomes. In early 2013, U.S. scientists showed it could be used to genetically engineer any type of animal cells, including human ones, in a petri dish. But the Chinese researchers were the first to demonstrate that this approach can be used in primates to create offspring with specific genetic alterations.

"The idea that we can modify primates easily with this technology is powerful," says Jennifer Doudna, a professor of molecular and cell biology at the University of California, Berkeley, and a developer of CRISPR. The creation of primates with intentional gene alterations could lead to powerful new ways to study complex human diseases. It also poses new ethical dilemmas. From a technical perspective, the Chinese primate research suggests that scientists could probably alter fertilized human eggs with CRISPR; if monkeys are any guide, such eggs could grow to be genetically modified babies. But "whether that would be a good idea is a much harder question," says Doudna.

The prospect of designer babies remains remote and far from the minds of most researchers developing CRISPR. Far more imminent are the potential opportunities to create animals with mutations linked to human disorders. Experimenting with primates is expensive and can raise concerns about animal welfare, says Doudna. But the demonstration that CRISPR works in monkeys has gotten "a lot of people thinking about cases where primate models may be important."

At the top of that list is the study of brain disorders. Robert Desimone, director of MIT's McGovern Institute for Brain Research, says that there is "quite a bit of interest" in using CRISPR to generate monkey models of diseases like autism, schizophrenia, Alzheimer's disease, and bipolar disorder. These disorders are difficult to study in mice and other rodents; not only do the affected behaviors differ substantially between these animals and humans, but the neural circuits involved in the disorders can be different. Many

JOHN MACNEILL; SOURCE: *CELL*



3 Surrogate mother

Researchers transfer healthy-looking embryos, now dividing into many cells, into female monkeys. Typically, three embryos are transferred into a surrogate.

4 Primate babies

The twins Mingming and Lingling are born with multiple genetic changes, the first live primates created in experiments using CRISPR genome editing.

experimental psychiatric drugs that appeared to work well in mice have not proved successful in human trials. As a result of such failures, many pharmaceutical companies have scaled back or abandoned their efforts to develop treatments.

Primate models could be especially helpful to researchers trying to make sense of the growing number of mutations that genetic studies have linked to brain disorders. The significance of a specific genetic variant is often unclear; it could be a cause of a disorder, or it could just be indirectly associated with the disease. CRISPR could help researchers tease out the mutations that actually cause the disorders: they would be able to systematically introduce the suspected genetic variants into monkeys and observe the results. CRISPR is also useful because it allows scientists to create animals with different combinations of mutations, in order to assess which ones—or which combinations of them—matter most in causing disease. This complex level of manipulation is nearly impossible with other methods.

Guoping Feng, a professor of neuroscience at MIT, and Feng Zhang, a colleague at the Broad Institute and McGovern Brain Institute who showed that CRISPR could be used to modify the genomes of human cells, are working with Chinese researchers to create macaques with a version of autism. They plan to mutate a gene called *SHANK3* in fertilized eggs, producing monkeys that can be used to study the basic science of the disorder and test possible drug treatments. (Only a small percentage of people with autism have the *SHANK3* mutation, but it is one of the few genetic variants that lead to a high probability of the disorder.)

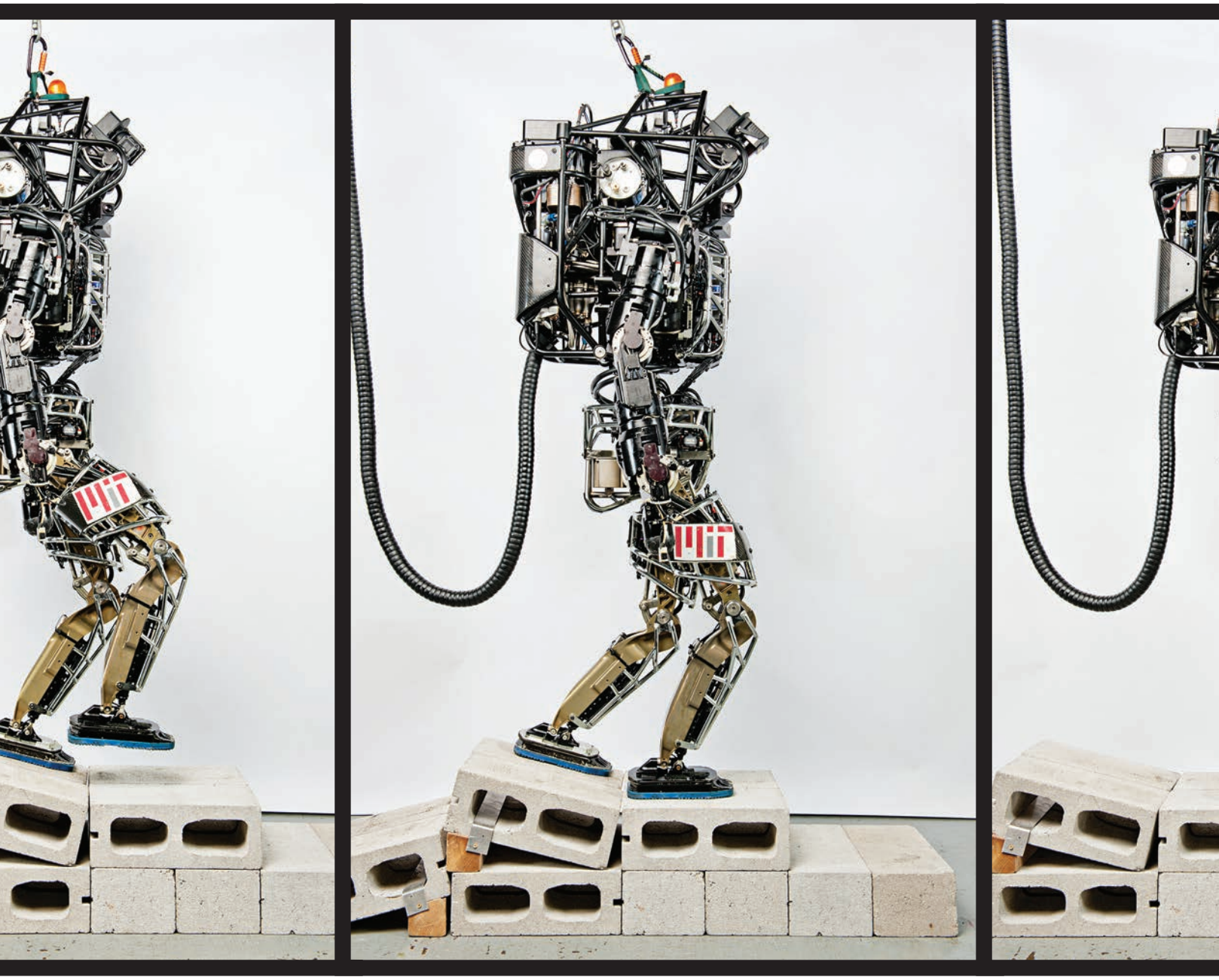
The Chinese researchers responsible for the birth of the genetically engineered monkeys are still focusing on developing the technology, says Weizhi Ji, who helped lead the effort at the Yunnan Key Laboratory of Primate Biomedical Research in Kunming. However, his group hopes to create monkeys with Parkinson's, among other brain disorders. The aim would be to look for early signs of the disease and study the mechanisms that allow it to progress.

The most dramatic possibility raised by the primate work, of course, would be using CRISPR to change the genetic makeup of human embryos during in vitro fertilization. But while such manipulation should be technically possible, most scientists do not seem eager to pursue it.

Indeed, the safety concerns would be daunting. When you think about "messing with a single cell that is potentially going to become a living baby," even small errors or side effects could turn out to have enormous consequences, says Hank Greely, director of the Center for Law and the Biosciences at Stanford. And why even bother? For most diseases with simple genetic causes, it wouldn't be worthwhile to use CRISPR; it would make more sense for couples to "choose a different embryo that doesn't have the disease," he says. This is already possible as part of in vitro fertilization, using a procedure called preimplantation genetic diagnosis.

It's possible to speculate that parents might wish to alter multiple genes in order to reduce children's risk, say, of heart disease or diabetes, which have complex genetic components. But for at least the next five to 10 years, that, says Greely, "just strikes me as borderline crazy, borderline implausible." Many, if not most, of the traits that future parents might hope to alter in their kids may also be too complex or poorly understood to make reasonable targets for intervention. Scientists don't understand the genetic basis, for instance, of intelligence or other higher-order brain functions—and that is unlikely to change for a long time.

Ji says creating humans with CRISPR-edited genomes is "very possible," but he concurs that "considering the safety issue, there would still be a long way to go." In the meantime, his team hopes to use genetically modified monkeys to "establish very efficient animal models for human diseases, to improve human health in the future."



Computer scientists have created machines that have the balance and agility to walk and run across rough

Agile

Webb Chappell

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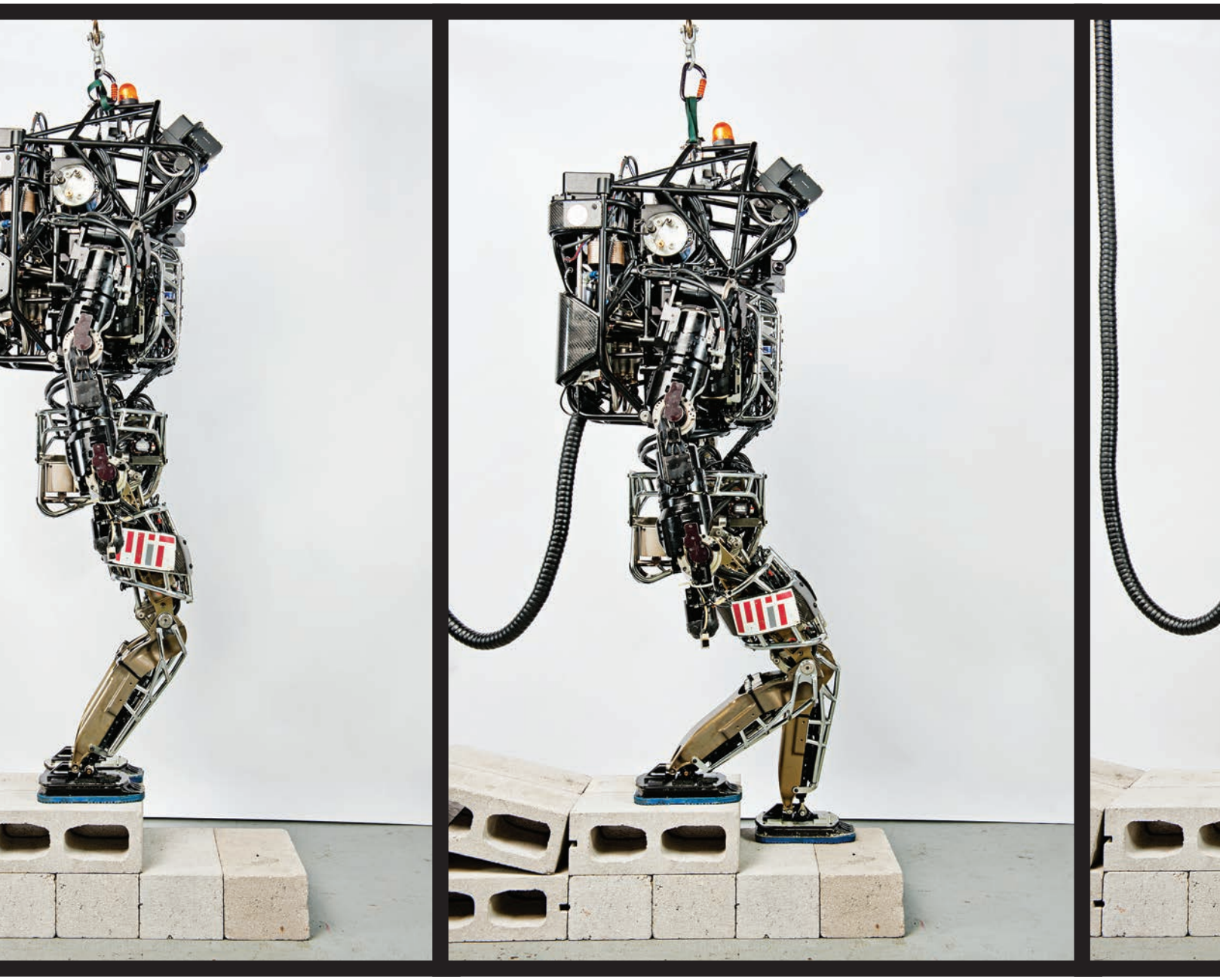
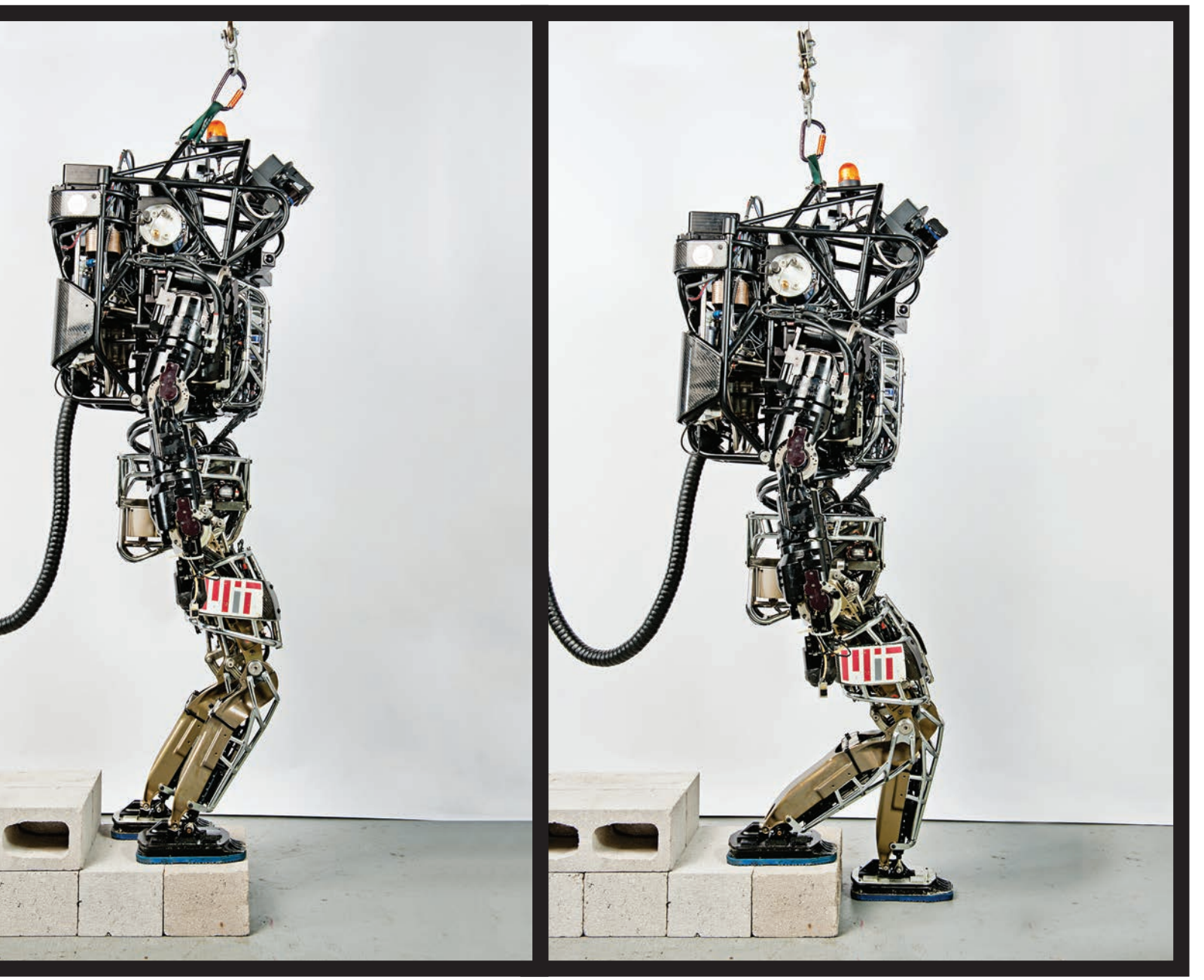


and uneven terrain, making them far more useful in navigating human environments. BY Will Knight

Robots



Breakthrough
Legged machines that stride over uneven or unsteady terrain.

Why It Matters
Much of the world is inaccessible to wheeled machines but not legged ones.

Key Players
- Boston Dynamics
- Schaft
- Honda

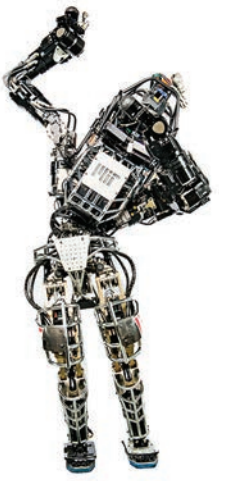
WALKING IS AN EXTRAORDINARY FEAT OF BIOMECHANICAL engineering. Every step requires balance and the ability to adapt to instability in a split second. It requires quickly adjusting where your foot will land and calculating how much force to apply to change direction suddenly. No wonder, then, that until now robots have not been very good at it.

Meet Atlas, a humanoid robot created by Boston Dynamics, a company that Google acquired in December 2013. It can walk across rough terrain and even run on flat ground. Although previous robots such as Honda's ASIMO and Sony's diminutive QRIO are able to walk, they cannot quickly adjust their balance; as a result, they are often awkward, and limited in practical value. Atlas, which has an exceptional sense of balance and can stabilize itself with ease, demonstrates the abilities that robots will need to move around human environments safely and easily.

Robots that walk properly could eventually find far greater use in emergency rescue operations. They could also play a role in routine jobs such as helping elderly or physically disabled people with chores and daily tasks in the home.

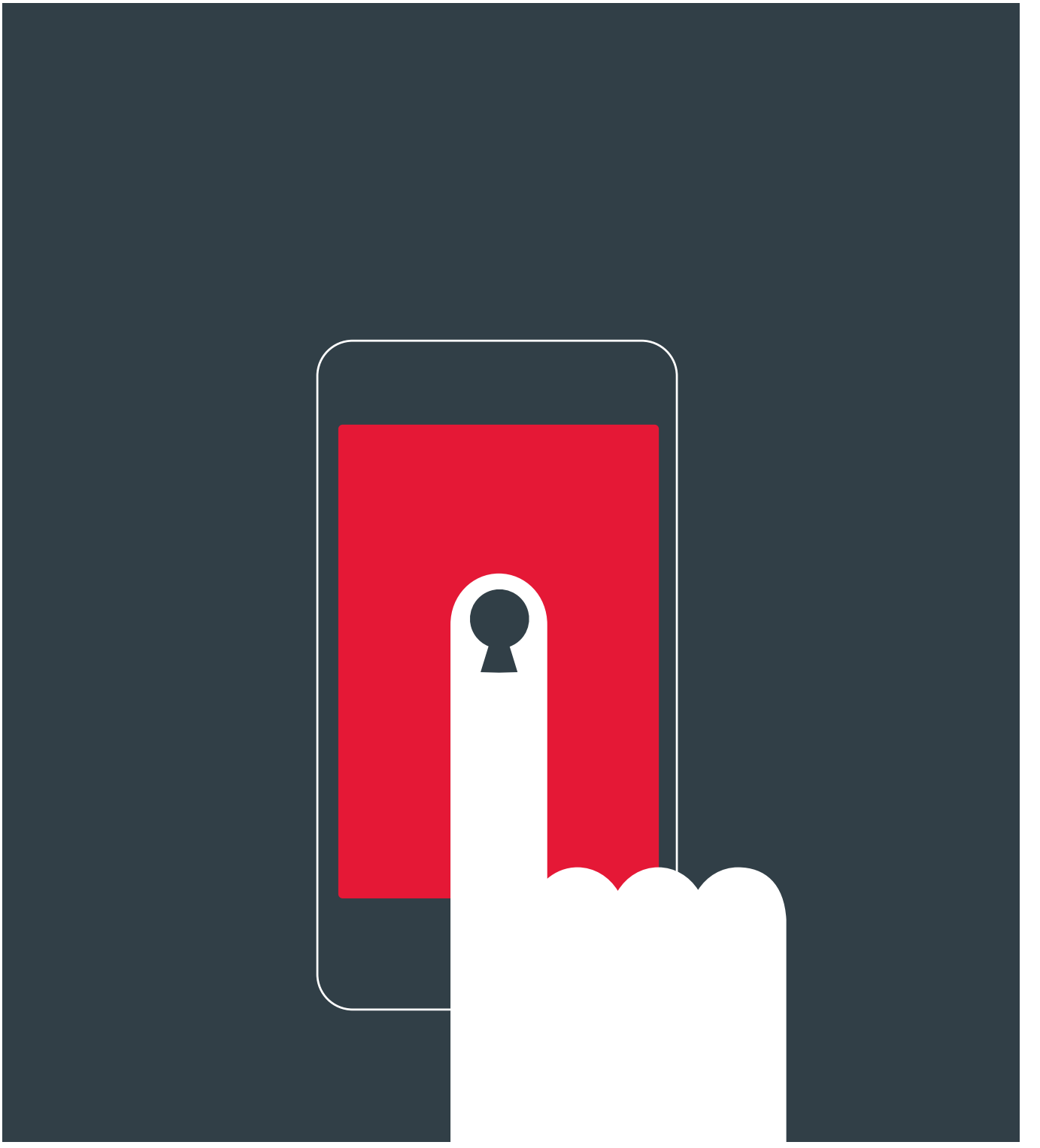
Marc Raibert, cofounder of Boston Dynamics, pioneered machines with "dynamic balance"—the use of continual motion to stay upright—in the early 1980s. As a professor at Carnegie Mellon University, he built a one-legged robot that leaped around his lab like a pogo stick possessed, calculating with each jump how to reposition its leg and its body, and how aggressively to push itself off the ground with its next bound. Atlas demonstrates dynamic balance as well, using high-powered hydraulics to move its body in a way that keeps it steady. The robot can walk across an unsteady pile of debris, walk briskly on a treadmill, and stay balanced on one leg when whacked with a 20-pound wrecking ball. Just as you instinctively catch yourself when pushed, shifting your weight and repositioning your legs to keep from falling over, Atlas can sense its own instability and respond quickly enough to right itself. The possibilities opened up by its humanlike mobility surely impressed Google. Though it's not clear why the company is acquiring robotics businesses, it bought seven others last year, including ones specializing in vision and manipulation.

Atlas isn't ready to take on home or office chores: its powerful diesel engine is external and noisy, and its titanium limbs thrash around dangerously. But the robot could perform repair work in environments too dangerous for emergency workers to enter, such as the control room of a nuclear power plant on the brink of a meltdown. "If your goals are to make something that's the equivalent of a person, we have a ways to go," Raibert says. But as it gets up and running, Atlas won't be a bad example to chase after.



Preceding pages: Researchers at MIT, led by Seth Teller and Russ Tedrake, replaced the dynamic balance software that comes with Atlas with their own version. This lets the robot walk relatively quickly over uneven and unfamiliar ground.

Right: The MIT software lets Atlas contort itself into exaggerated physical positions without falling over.



Noma Bar

New models built with security and privacy in mind reflect the Zeitgeist of the Snowden era.

Breakthrough
Mobile phones for the consumer market that transmit minimal personal information.

Why It Matters
Governments and advertisers gather intimate details from cell phones.

Key Players
- Blackphone
- Cryptophone
- Whisper Systems

Ultraprivate Smartphones

BY
David Talbot

ON JANUARY 21 A TEXT MESSAGE FLASHED on phones held by the protesters thronging Kiev's Independence Square. Ukraine's president, Viktor Yanukovych, was then still clinging to power and brutalizing opponents. The message—from the number 111—read: *"Dear subscriber, you are registered as a participant in a mass disturbance."* Widely presumed to have been sent from Yanukovych's security apparatus to all phones in the protest zone, the message was a stark reminder of how mobile phones can be used for surveillance.

Soon after, a Ukrainian man walked into a nondescript office in National Harbor, Maryland, and sought help from a man named Phil Zimmermann.

Zimmermann is a cryptologist. His company, Silent Circle, encrypts voice calls, text messages, and any file attachments. If you use Silent Circle, your calls to other users are sent through the company's servers and decrypted on the other phone. The service won't stop the delivery of ominous messages in range of certain base stations. But it can block eavesdropping and prevent the snooper from knowing the number of the person you are calling or texting. Soon, access codes for Silent Circle were making their way to protest organizers in the heart of Kiev. "Those are the kinds of environments where you need widespread deployment of crypto technology," Zimmermann says, with evident satisfaction.

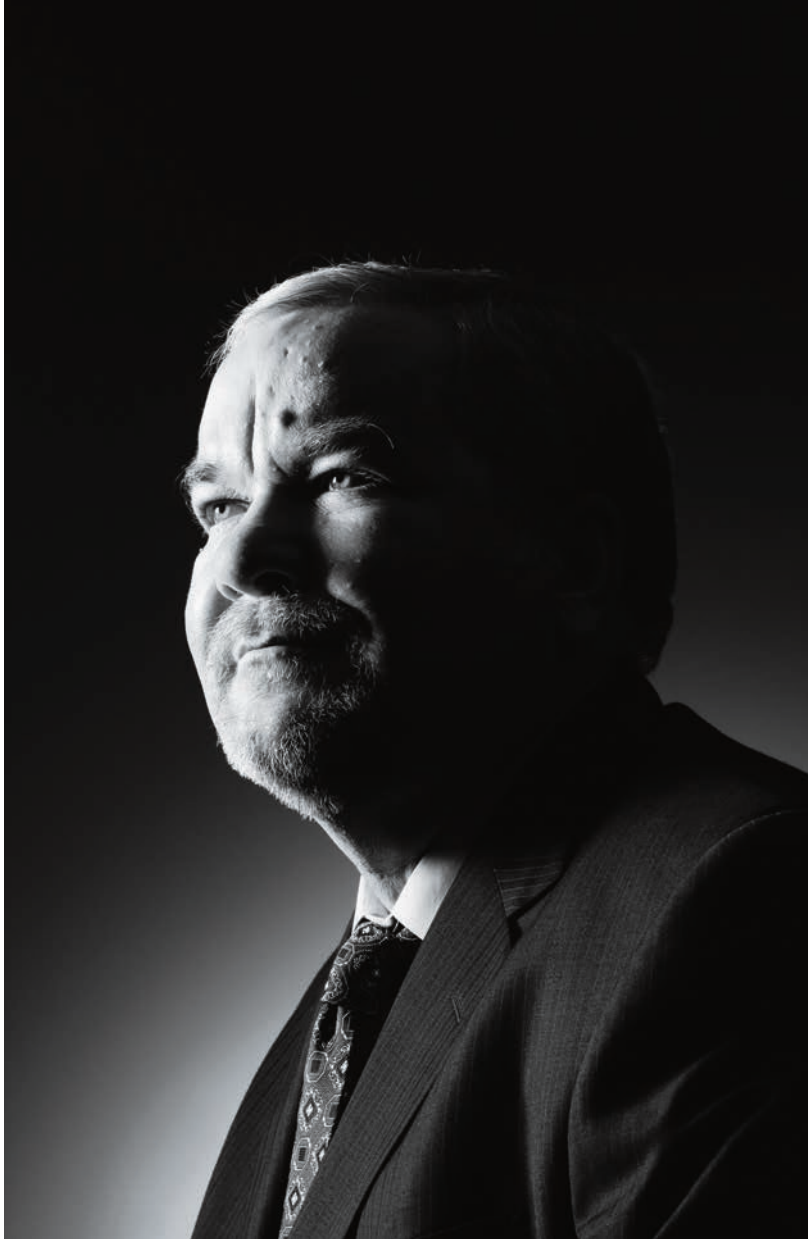
In the past year, it's become clearer that places like Kiev are not the only environments where people might want the privacy Zimmermann can provide. Documents brought to light by former U.S. National Security Agency contractor Edward Snowden suggest that the NSA gathers huge amounts of information from cloud computing platforms and wireless carriers, including the numbers ordinary people called and the times they called them. Not only could the government be watching you: so could websites, advertisers, and even retailers trying to track your movements within stores. Modern smartphones and the apps running on them are engineered to collect and disseminate enormous amounts of user data—such as location, Web browsing histories, search terms, and contact lists.

By summer Zimmermann will be delivering a new way to fight back: a highly secure smartphone, called Blackphone. Now being manufactured by a joint venture that includes Silent Circle, it uses Zimmermann's encryption tools and adds other protections. It runs a special version of the Android operating system—PrivatOS—that blocks many of the ways phones leak data about your activities. While custom security phones have long been in the hands of military and government leaders, this effort may signal a shift toward mass-market phones that are far more private and secure.

Blackphone, which sells for $629 with subscriptions to privacy-protecting services, is one of many measures that technologists are taking in response to the Snowden revelations. One such effort involves wider encryption of ordinary Web traffic. Stephen Farrell, a computer scientist at Trinity College Dublin who is leading that project through the Internet Engineering Task Force, says a phone that encrypts communications and seals off data leaks is a crucial part of the strategy. "Personally, I really would like to have a phone with a much more hardened and privacy-friendly configuration," he says.

Crypto Warrior

Growing up in Florida, Phil Zimmermann liked breaking into places and things: his youthful conquests included Disney World and the Miami Seaquarium. He studied computer science at Florida Atlantic University, and he became interested in cryptography in the 1970s, when papers on a technology called public-key cryptography emerged. Traditional crypto required the parties in an encrypted conversation to possess the same unique decoding tool (or "key"). The new approach was fundamentally different: it involved two mathematically linked keys, one private, the other



Privacy software from Zimmermann is key to Blackphone. "Like Steve Jobs said, if you want to do good software you want to build the computer, too," he says.

public. Suddenly, applications such as digital signatures became possible. You could use a private key to "sign" a document; later, anyone else could use the public key to verify that you were indeed the author.

Zimmermann's fascination with this new tool dovetailed with an activist streak. In the 1980s, while laboring as a software engineer by day, he was a peace activist by night, working on the nuclear weapons freeze movement and getting arrested at the Nevada nuclear test site. (He tells of seeing actor Martin Sheen and the celebrity scientist Carl Sagan in jail.) He viewed the Reagan White House as a threat to peace and human rights as it battled socialist movements and governments. He soon started putting his interests together. "I wanted to make crypto software to protect the grassroots community, for the people of El Salvador, for human-rights groups," he says.

He eventually came up with something new for applications like e-mail. Now known as PGP, for "pretty good privacy," it built on public-key cryptography with a few new tricks, using speedier algorithms and binding things like usernames and e-mail addresses to public keys. PGP quickly became the most popular way to encrypt e-mail. It also made Zimmermann a combatant in the so-called crypto wars of the 1990s. At the time, the U.S. government was worried about the prospect of strong encryption technologies slipping out of the country and making it harder to snoop on other countries. So after Zimmermann published his code on the Internet in 1991, the Justice Department opened a criminal investigation. It wasn't dropped until 1996. By then, any fears that foreign governments would use cryptography to hide their activities from the U.S. were overshadowed by the great potential the technology had for American companies in the globalized business environment that emerged after the Cold War. Businesses were opening offices and factories in cheap labor markets, "which tend to be in countries with aggressive wiretapping environments and low on human rights," Zimmermann says. These businesses were now facing threats once faced only by human-rights and political activists. To better serve that market, Zimmermann began selling cryptography tools through a startup, PGP Inc.

Zimmermann always wanted to take widespread encryption to the next level: secure telephony. Until the past few years, however, voice transmissions did not generally take the digital form required by cryptographic technologies. In the 1990s he'd built a prototype, but it required using modems tethered to PCs. "That product was never going to get any traction," he says. Today, telephone companies and carriers do encrypt calls—but they hold the crypto keys in their servers, and "phone companies have historically been very coöperative with wiretapping," he says. Zimmermann's protocols instead kept the keys only at endpoints—preventing the carriers and even his own servers from decrypting the content of a call.

These days, almost all telephony is digital—not just obvious forms like Skype, but cellular and landlines, too. So when a former U.S. Navy SEAL, Mike Janke, approached Zimmermann in 2011 with an idea for providing a service to help U.S. military members make secure calls home, he was game. They joined with Jon Callas, creator of Apple's whole-disk encryption, to found Silent Circle. (The company originally offered e-mail, too—a service called Silent Mail. But many users were opting to store keys with Silent Mail,

Joseph Victor Stefanchik

leaving the company vulnerable to an NSA request for data. The team killed Silent Mail and is rebuilding it so it stores the keys differently.)

No Breadcrumbs

Silent Circle had a missing piece: the hardware. "Over the years, when people asked 'How safe can I be using your crypto software?' I had to say, 'We think we have some good crypto here, but the computer you are running it on might be owned by a hacker, and it won't matter," Zimmermann says. "With Blackphone we are trying to do something about that."

Blackphone is an amalgamation of technologies. Silent Circle provides the encrypted voice and text services; the device is being made by Geeksphone, a Spanish company that specializes in phones that run open-source operating systems. Together they created PrivatOS, which gives more control over what data apps can see, encrypts data stored on the phone, and allows you to get wireless security updates directly from Blackphone, rather than relying on carriers. The two companies also brought on other vendors of privacy and security services. For example, one blocks tracking companies from seeing the websites you visit and the searches you make.

By February, they had one carrier lined up to sell the phone (though any buyer could use it and put a SIM card in it): Netherlands-based KPN, which also serves Belgium and Germany. They were talking to other carriers, too. It would be "the unique device that nobody has dared to make yet," said Geeksphone's 22-year-old founder, Javier Agüera—at least, nobody who had the average user in mind.

Fast-forward to late February. Zimmermann and his team sat at a sidewalk restaurant in Barcelona, munching tapas. It was the eve of Blackphone's launch at the largest mobile trade show, Mobile World Congress. Early versions of the phone were in their pockets. As I joined the group and learned more about the phone, I became aware of my digital nakedness. I glanced at my new iPhone 5S. Opening my Wi-Fi settings, I saw available networks called Barcelona Wi-Fi, Cbarc 1, Spyder, and several others. All were of unknown trustworthiness, but I didn't think it mattered; after all, I wasn't connecting with any of them. But it turns out that my phone's automatic process of seeking such signals meant it was notifying those routers of my phone's ID number. This is already being exploited by retailers, who use Wi-Fi probes to track customers' habits. And because information from apps is merged with data from Web browsers, shopping sites, and other sources, dozens of companies can use that ID number to keep tabs on me.

Mike Kershaw, Blackphone's chief architect, came over to my side of the table. He proudly explained how Blackphone would prevent any such thing. Software Kershaw developed programs the phone not to search for Wi-Fi signals unless it is in a predefined geographical area, such as one around your home or office. So as we ate tapas, I was the only person at the table leaving digital breadcrumbs. The others had tools to prevent browsing history and search terms from being tied to their identity; I didn't. They had fine-grained control over app permissions; I didn't.

The next morning, near a modest booth at Mobile World Congress, some 200 journalists and analysts crowded the hallways for Blackphone's launch announcement. "We are not a phone company adding a privacy feature," Zimmermann said. "We are a privacy company selling a phone." But it was already clear that this was a kind of anti-phone, going against the grain of the mainstream smartphone industry. Later that day, Zimmermann walked by Samsung's enormous installation. It was bristling with Galaxy 5 phones, loaded with Android configured largely the way Google likes it: to gather data. "They've got a pretty big booth," Zimmermann deadpanned.

Not NSA-Proof

Top security experts are reserving judgment on Blackphone until they can test the phone. It won't ship until June. But the underlying encryption Silent Circle uses—and the evident paranoia of its creators—is widely admired. "I very much like Silent Circle's solutions," says Bruce Schneier, a cryptologist who has been calling for more security in communication technologies and wider use of encryption.

While the phone is resistant to everyday threats like hacking and snooping by data brokers, even the company concedes that it's not NSA-proof, and it could have an Achilles' heel: the apps that its users will inevitably download. Xuxian Jiang, a computer scientist at North Carolina State University and an authority on Android security, says that's how devices acquire many of their vulnerabilities. Blackphone also doesn't protect e-mail on its own; whether your e-mail uses encryption technology such as PGP depends on your e-mail provider. Still, Jiang says of the phone: "These are certainly good privacy improvements."

There are a few competing efforts. A company owned by Twitter, Whisper Systems, has released an encryption system for Android calls. Nonetheless, Blackphone is already establishing itself: by March, Zimmermann says, hundreds of thousands of units had been ordered. The company expects to sell millions of phones in the first two years. In many ways, the NSA revelations, the growing awareness of how consumers are being tracked by commercial interests, and conflicts like the one in Ukraine have been the best possible advertising. "It used to be an uphill battle to make people believe there was a need for this kind of technology," Zimmermann says. "Not anymore." T

Inks made from different types of materials, precisely applied, are greatly expanding the kinds of things that can be printed.

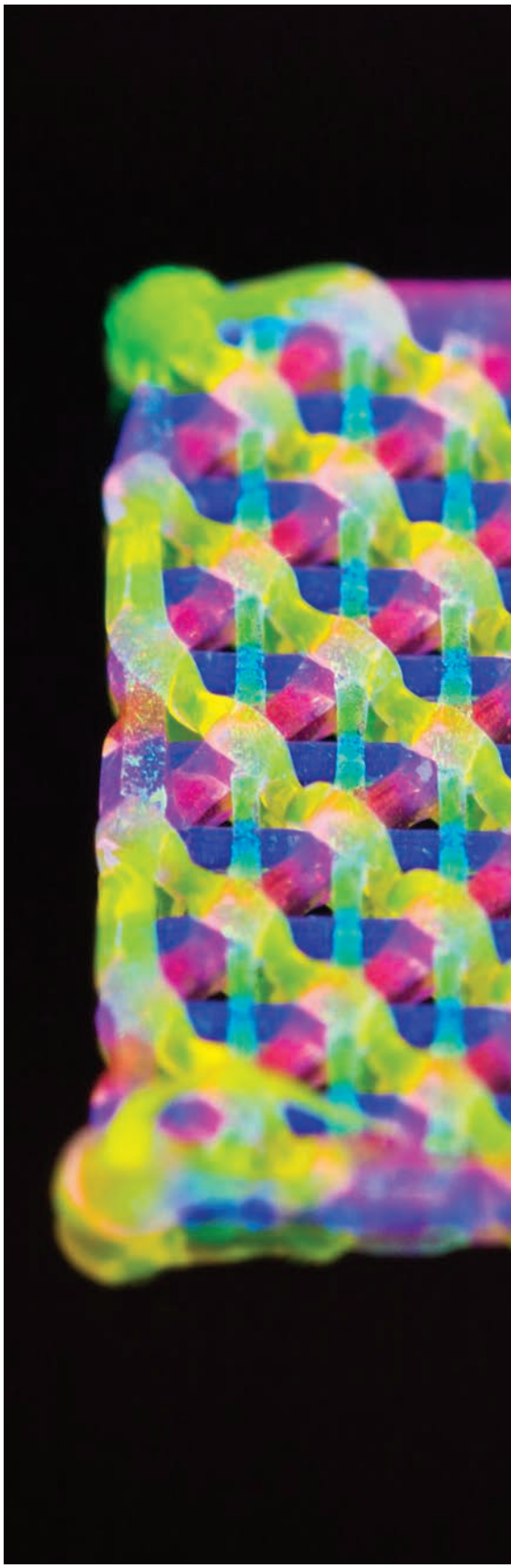
Breakthrough
3-D printing that uses multiple materials to create objects such as biological tissue with blood vessels.

Why It Matters
Making biological materials with desired functions could lead to artificial organs and novel cyborg parts.

Microscale 3-D Printing

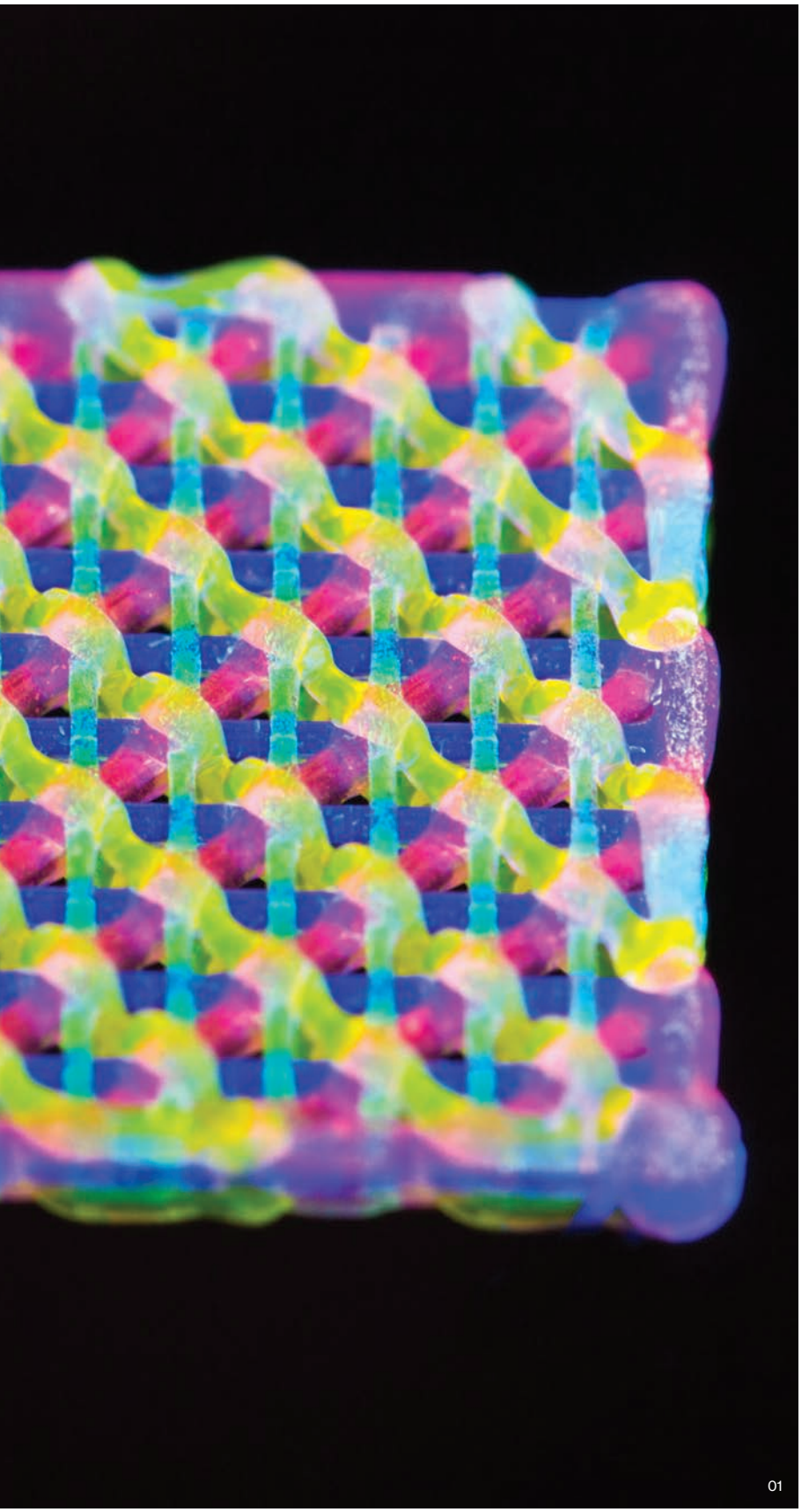
BY
David Rotman

Key Players
- Jennifer Lewis, Harvard University
- Michael McAlpine, Princeton University
- Keith Martin, University of Cambridge



DESPITE THE EXCITEMENT THAT 3-D printing has generated, its capabilities remain rather limited. It can be used to make complex shapes, but most commonly only out of plastics. Even manufacturers using an advanced version of the technology known as additive manufacturing typically have expanded the material palette only to a few types of metal alloys. But what if 3-D printers could use a wide assortment of different materials, from living cells to semiconductors, mixing and matching the "inks" with precision?

Jennifer Lewis, a materials scientist at Harvard University, is developing the chemistry and machines to make that possible. She prints intricately shaped objects from "the ground up," precisely adding materials that are useful for their mechanical properties, electrical conductivity, or optical traits. This means 3-D printing technology could make objects that sense and respond to their environment. "Integrating form and function," she says, "is the next big thing that needs to happen in 3-D printing."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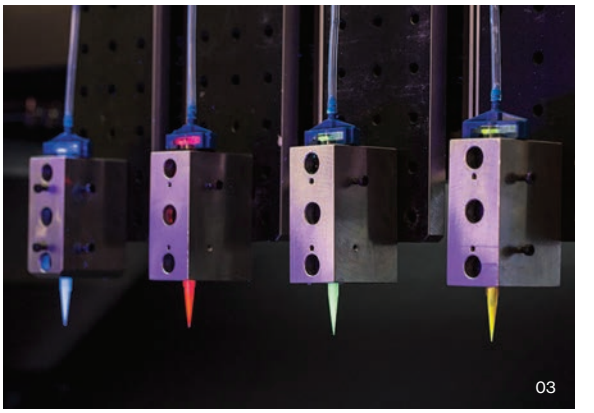
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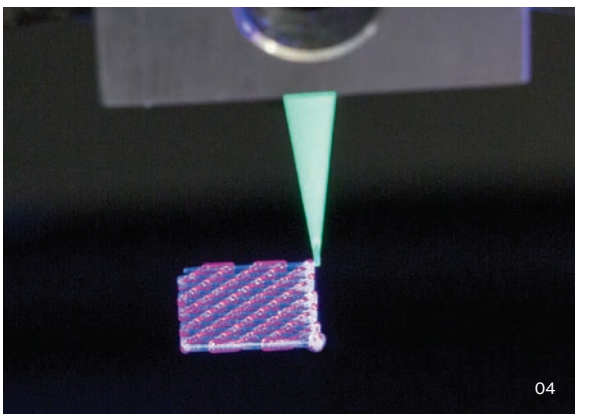
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Printing intricate shapes

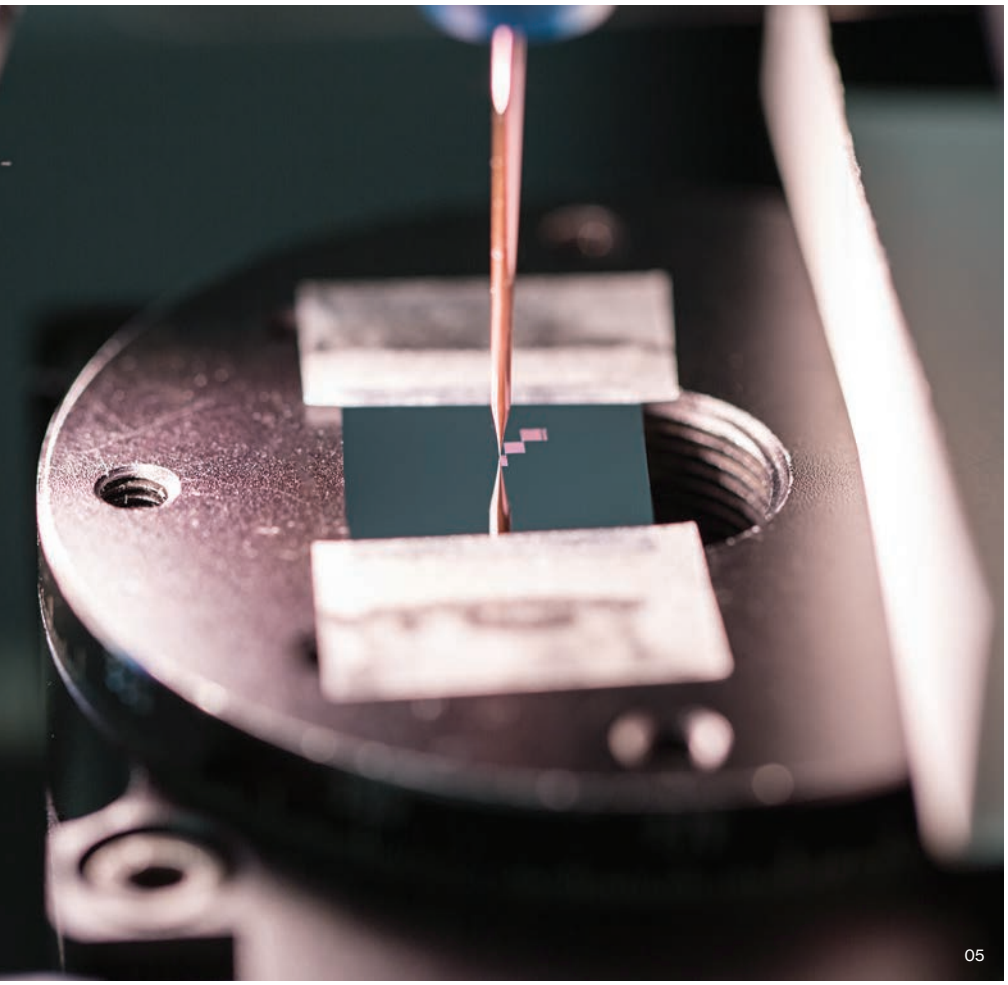
01 To show off its ability to do multimaterial 3-D printing, Lewis's lab has printed a complex lattice using different inks.

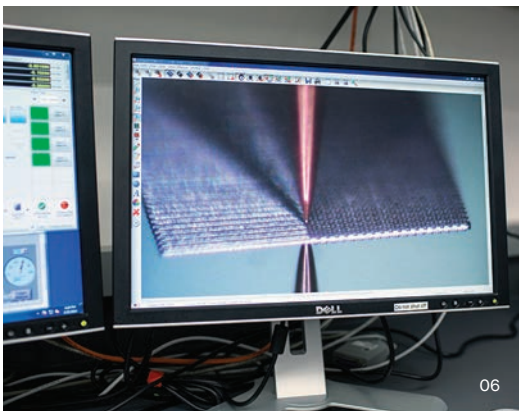
02 For the demonstration, the group formulated four polymer inks, each dyed a different color.

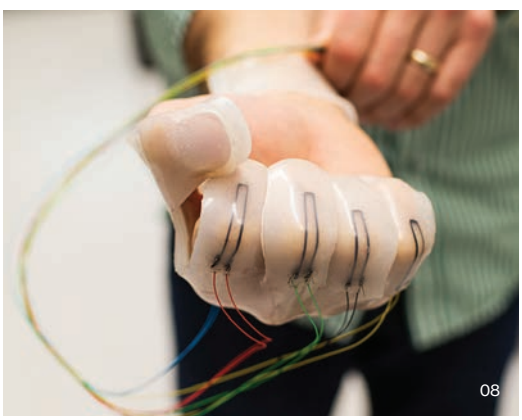
03 The different inks are placed in standard print heads.

04 By sequentially and precisely depositing the inks in a process guided by the group's software, the printer quickly produces the colorful lattice.

Ken Richardson







Nanosilver inks and flexible sensors

05 Inks made of silver nanoparticles are used to print electrodes as small as a few micrometers.

06 As in the other 3-D printing processes, the operation is controlled and monitored by computers.

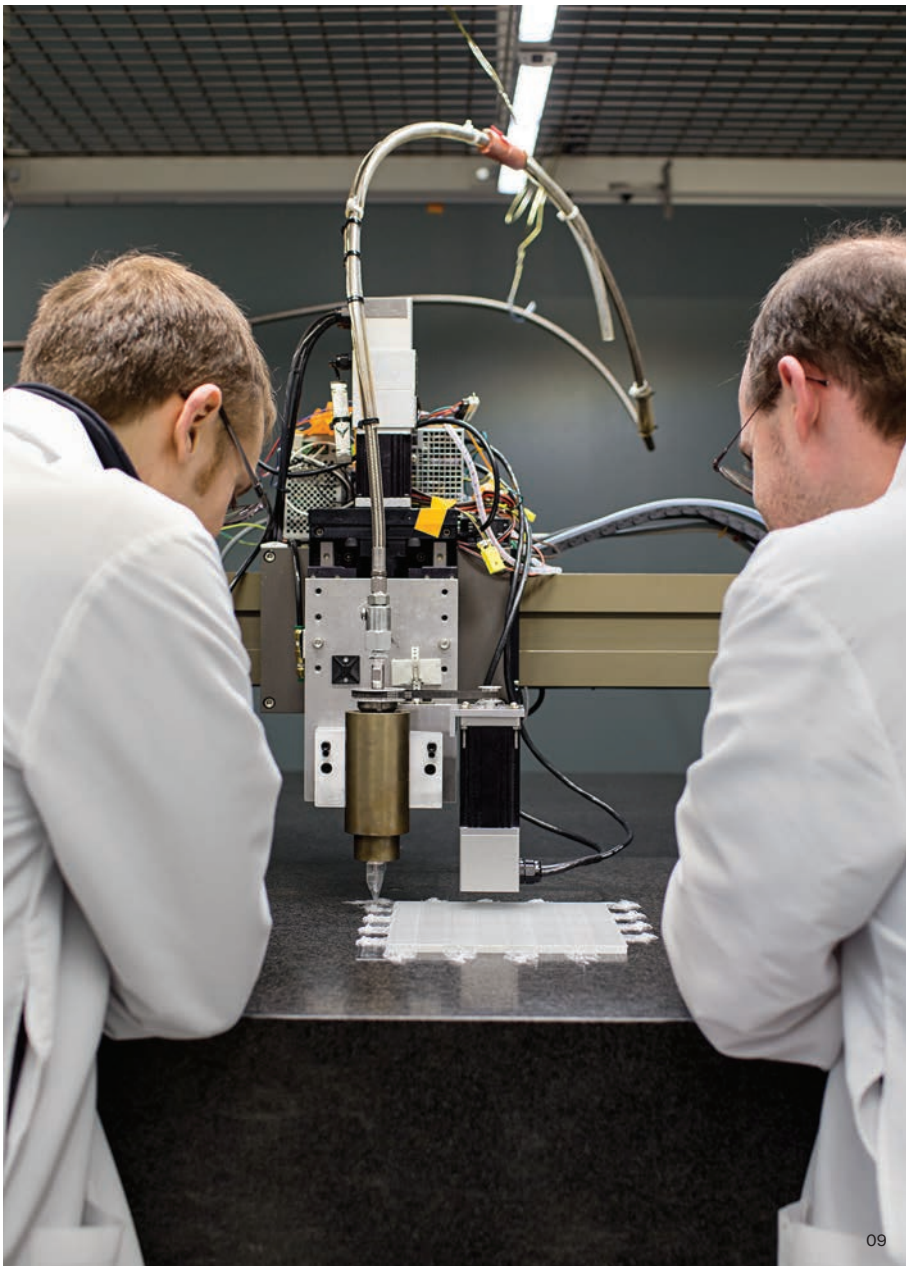
07 Jennifer Lewis's goal is to print complex architectures that integrate form and function.

08 A glove with strain sensors is made by printing electronics into a stretchable elastomer.

A group at Princeton University has printed a bionic ear, combining biological tissue and electronics (see "Cyborg Parts," September/October 2013), while a team of researchers at the University of Cambridge has printed retinal cells to form complex eye tissue. But even among these impressive efforts to extend the possibilities of 3-D printing, Lewis's lab stands out for the range of materials and types of objects it can print.

Last year, Lewis and her students showed they could print the microscopic electrodes and other components needed for tiny lithium-ion batteries (see "Printing Batteries," January/February). Other projects include printed sensors fabricated on plastic patches that athletes could one day wear to detect concussions and measure violent impacts. Most recently, her group printed biological tissue interwoven with a complex network of blood vessels. To do this, the researchers had to make inks out of various types of cells and the materials that form the matrix supporting them. The work addresses one of the lingering challenges in creating artificial organs for drug testing or, someday, for use as replacement parts: how to create a vascular system to keep the cells alive.

In a basement lab a few hundred yards from Lewis's office, her group has jury-rigged a 3-D printer, equipped with a microscope, that can precisely print structures with features as small as one micrometer (a human red blood cell is around 10 micrometers in diameter). Another, larger 3-D printer, using print-



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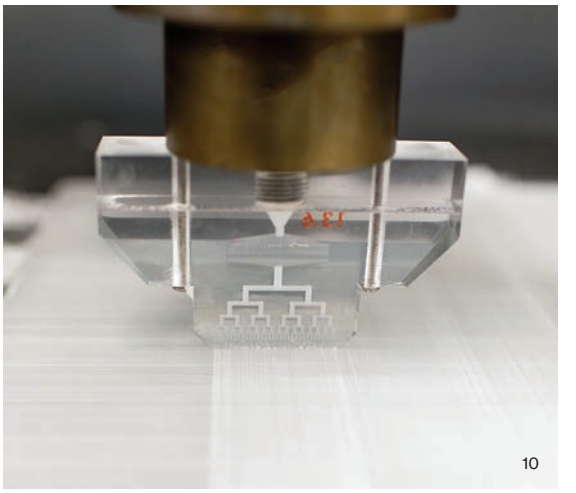

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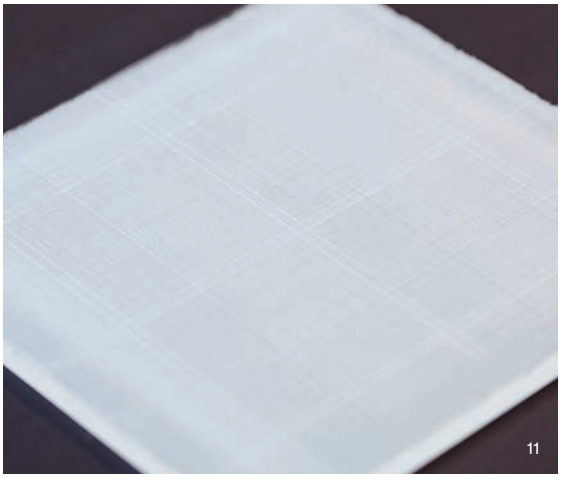


11

Speed counts

09 The largest printer in Lewis's lab makes objects up to a meter by a meter.

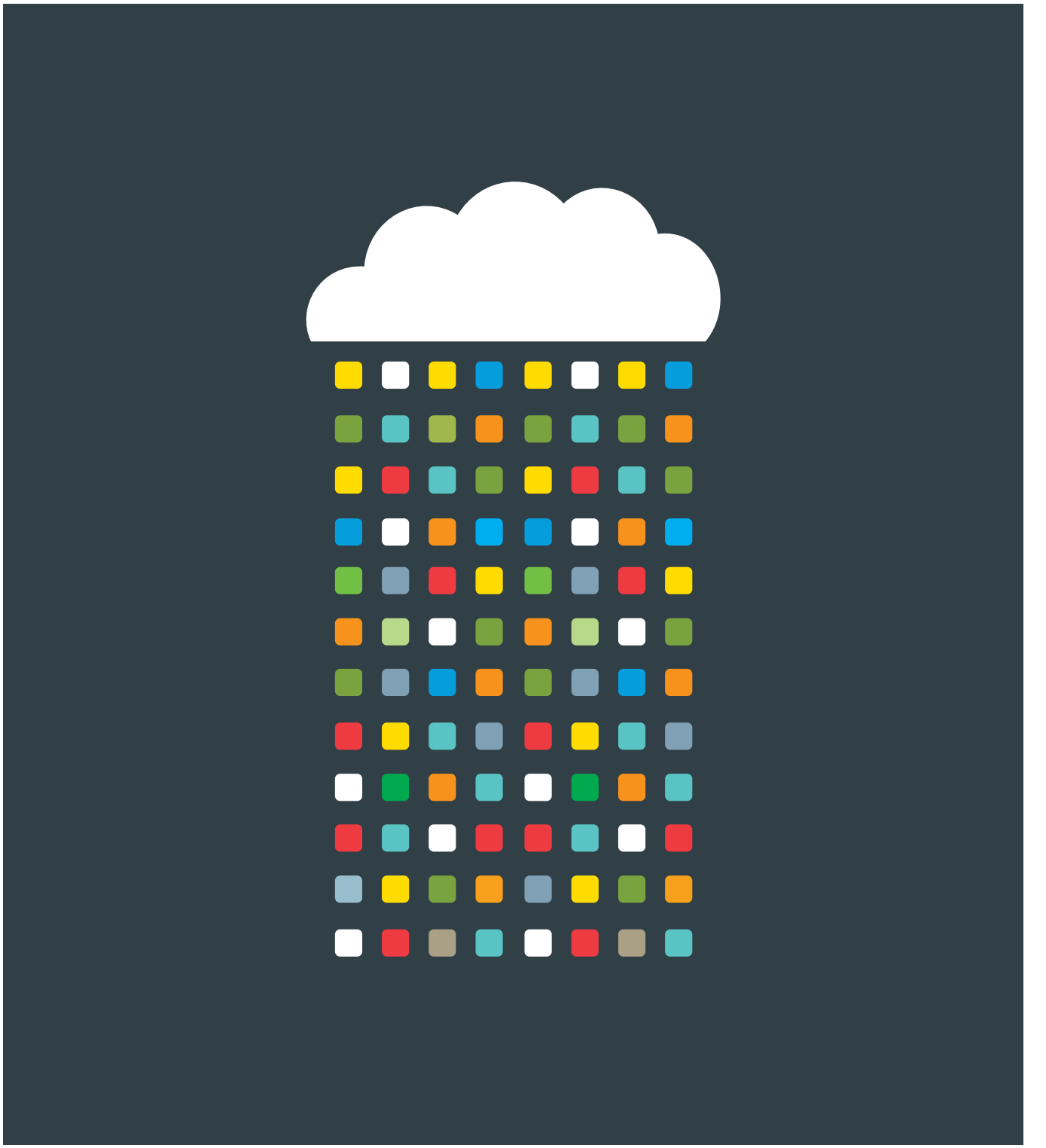
10 For such jobs, the printer uses a 64- or 128-nozzle array to speed up the process.

11 A test sample with a layered microstructure was printed in minutes using wax ink.

ing nozzles with multiple outlets to print multiple inks simultaneously, can fabricate a meter-sized sample with a desired microstructure in minutes.

The secret to Lewis's creations lies in inks with properties that allow them to be printed during the same fabrication process. Each ink is a different material, but they all can be printed at room temperature. The various types of materials present different challenges; cells, for example, are delicate and easily destroyed as they are forced through the printing nozzle. In all cases, though, the inks must be formulated to flow out of the nozzle under pressure but retain their form once in place—think of toothpaste, Lewis says.

Before coming to Harvard from the University of Illinois at Urbana-Champaign last year, Lewis had spent more than a decade developing 3-D printing techniques using ceramics, metal nanoparticles, polymers, and other nonbiological materials. When she set up her new lab at Harvard and began working with biological cells and tissues for the first time, she hoped to treat them the same way as materials composed of synthetic particles. That idea might have been a bit naïve, she now acknowledges. Printing blood vessels was an encouraging step toward artificial tissues capable of the complex biological functions found in organs. But working with the cells turns out to be "really complex," she says. "And there's a lot more that we need to do before we can print a fully functional liver or kidney. But we've taken the first step." T



Noma Bar

The smartphone era is finally getting the productivity software it needs.

Breakthrough
Services that make it fruitful to create and edit documents on mobile devices.

Why It Matters
Much of today's office work is done outside an office.

Key Players
- Quip
- Quickoffice
- Box
- Dropbox
- Microsoft
- Google
- CloudOn

Mobile Collaboration

BY
Ted Greenwald

ONE AFTERNOON LAST FALL, DAVID Levine took the subway from his office in lower Manhattan to a meeting at Rockefeller Center in midtown. The 35-year-old CIO of the startup investment firm Artivest was working on a blog post with colleagues and with freelancers in Boston and Crete. Levine used a new app called Quip to type the post on his iPhone, his wireless connection waxing and waning as the F train clattered through the tunnels. Quip let the team make changes, add comments, and chat via text, all presented in a Facebook-style news feed. Whenever Levine's connection returned, the app synchronized his contributions with everyone else's, so they all were working on the same version.

Had they been working with a traditional word-processing program, the process would probably have been a drawn-out round-robin of e-mail messages, proliferating attachments, and manual collation of disparate contributions. Instead, "by the time I got out of the subway, the post was done," Levine recalls, "and by the time I got out of the meeting, it was on the website."

It has taken a while for the software that helps people get work done to catch up with the fact that many people are increasingly working on tablets and phones. Now new apps are making it easier to create and edit documents on the go. Meanwhile, cloud-based file storage services, including Box, Dropbox, Google Drive, and Microsoft's OneDrive—which have plunged in cost and soared in usage—help keep the results in sync even as multiple users work on the same file simultaneously. Some cloud services do this by separating what look to users like unified files into separate entries—paragraphs, words, even individual characters—in easily manipulated databases. That lets them smoothly track and merge changes made by different people at different times.

But the most interesting new mobile collaboration services don't just replicate the software we're accustomed to using on desktop computers. They also highlight an aspect of group work that received scant attention in the days when coworkers gathered together in offices: the communication that is part and parcel of collaboration. That back-and-forth can have as much value as the content itself. It can keep the team on track, inform participants who join the process late, and spark new ideas.

In traditional word-processing software, much of that conversation gets lost in "notes," comments, or e-mail. But new document-editing apps capture the stream of collaborative communication and put it on equal footing with the nominal output of the process. Box's document-collaboration service Box Notes displays avatar icons along the left-hand margin to show who contributed what; CloudOn, a mobile editor for Microsoft Office documents, gives prime placement to both conversations (comments, messages) and tasks (editing, approvals, permissions); and Quip displays a running text-message thread.

"It's like you walked over to someone's desk and said, 'Read this and let me know if you have any questions,'" says Bret Taylor, Quip's founder and CEO, who was formerly CTO at Facebook. "It's a very personal, intimate experience that has been lost since the days of e-mail."

By incorporating streams of messages about the work being created, these apps reflect the fact that many communications are now brief, informal, and rapid. "Most younger people rely on short-form mobile messaging and use e-mail only for more formal communications," Taylor points out.

For Levine, who has been known to fire off a blog post before getting out of bed in the morning (much to his wife's dismay), this mobile way of working is far more consonant with the way he lives—striving to squeeze every last iota of productivity out of each moment. "It allows me to accomplish what I need to do without interrupting my flow," he says. Even when he's in a subway tunnel.

Smart Wind and Solar Power

Big data and artificial intelligence are producing ultra-accurate forecasts that will make it feasible to integrate much more renewable energy into the grid.

STORY AND PHOTOGRAPH BY
Kevin Bullis

Breakthrough
Ultra-accurate forecasting of wind and solar power.

Why It Matters
Dealing with the intermittency of renewable energy will be crucial for its expansion.

Key Players
- Xcel Energy
- GE Power
- National Center for Atmospheric Research

WIND POWER IS BOOMING ON THE OPEN plains of eastern Colorado. Travel seven miles north of the town of Limon on Highway 71 and then head east on County Road 3p, a swath of dusty gravel running alongside new power lines: within minutes you'll be surrounded by towering wind turbines in rows stretching for miles. Three large wind farms have been built in the area since 2011. A new one is going up this year.

Every few seconds, almost every one of the hundreds of turbines records the wind speed and its own power output. Every five minutes they dispatch data to high-performance computers 100 miles away at the National Center for Atmospheric Research (NCAR) in Boulder. There artificial-intelligence-based software crunches the numbers, along with data from weather satellites, weather stations, and other wind farms in the state. The result: wind power forecasts of unprecedented accuracy that are making it possible for Colorado to use far more renewable energy, at lower cost, than utilities ever thought possible.

The forecasts are helping power companies deal with one of the biggest challenges of wind power: its intermittency. Using small amounts of wind power is no problem for utilities. They are accustomed to dealing with variability—after all, demand for electricity changes from season to season, even from minute to minute. However, a utility that wants to use a lot of wind power needs backup power to protect against a sudden loss of wind. These backup plants, which typically burn fossil fuels, are expensive and dirty. But with more accurate forecasts, utilities can cut the amount of power that needs to be held in reserve, minimizing their role.

Before the forecasts were developed, Xcel Energy, which supplies much of Colorado's power, ran ads opposing a proposal that it use renewable sources for a modest 10 percent of its power. It mailed flyers to its customers claiming that such a mandate would increase electricity costs by as much as $1.5 billion over 20 years.

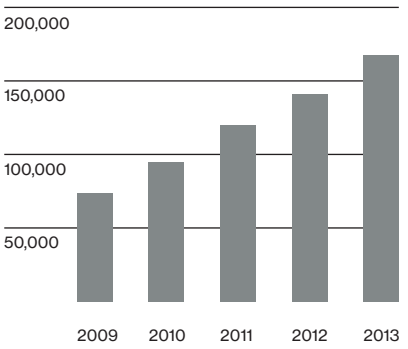
But thanks in large part to the improved forecasts, Xcel, one of the country's largest utilities, has made an about-face.

Turbines at this wind farm north of Limon, Colorado, collect and transmit massive amounts of data.

U.S. Wind Power Generation

Gigawatt-hours

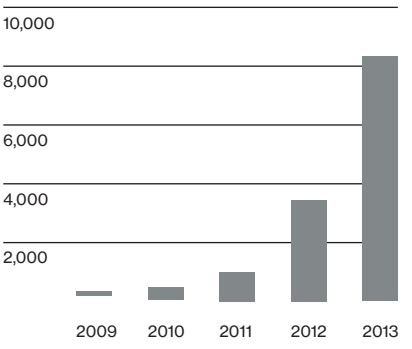
The amount of wind power has more than doubled since 2009.



U.S. Solar Power Generation

Gigawatt-hours

Solar power generation lags wind power production by about a decade.



It has installed more wind power than any other U.S. utility and supports a mandate for utilities to get 30 percent of their energy from renewable sources, saying it can easily handle much more than that.

An early version of NCAR's forecasting system was released in 2009, but last year was a breakthrough year—accuracy improved significantly, and the forecasts saved Xcel nearly as much money as they had in the three previous years combined. This year NCAR is testing a similar forecasting system for solar power.

Mining these detailed forecasts to develop a more flexible and efficient electricity system could make it much cheaper to hit ambitious international goals for reducing carbon emissions, says Bryan Hannegan, director of a $135 million facility at the National Renewable Energy Laboratory (NREL) in Golden, Colorado, that uses supercomputer simulations to develop ways to scale up renewable power. "We've got a line of sight to where we want to go in the long term with our energy and environment goals," he says. "That's not something we've been able to say before."

Chasing the Wind

No one is more aware of the challenges of integrating wind power into the grid than Dayton Jones, a power plant dispatcher for Xcel Energy. From his perch on the 10th floor of the Xcel building in downtown Denver, he's responsible for keeping the lights on in Colorado. Doing so requires matching power production to electricity demand by turning power plants on and off and controlling their output. Generating too much or too little power can damage electrical appliances or even plunge the grid into a blackout. Wind power, with its sharp fluctuations, makes his job harder.

A few years ago, dispatchers like Jones couldn't trust forecasts of how much wind power would be available to the grid at a given time. Those forecasts were typically off by 20 percent, and sometimes wind power completely failed to materialize when predicted. The solution was to have fossil-fuel plants idling, ready to replace all of that wind power in a few minutes. This approach is expensive, and the more the system is intended to rely on wind power, the more expensive it gets. What's more, running the backup fossil-fuel plants means you're "throwing carbon up into the sky," says William Mahoney, deputy director of the Research Applications Laboratory at NCAR. "It costs money, and it's bad for the environment."

NCAR's forecasts give Jones enough confidence in wind power to shut down many of the idling backup plants. The number varies depending on the certainty of the forecast. If the weather is cold and wet and there's a chance ice could form on wind turbines and slow them down or stop them from spinning, he might need enough fossil-fuel backup to completely replace his wind power.

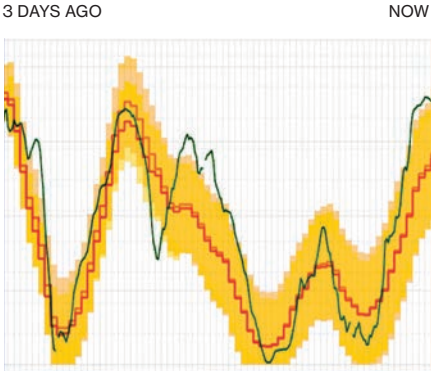
But on nice days with steady, abundant wind, he might shut down all his fast-response backup plants, even those normally reserved for responding to changes in demand. Under such circumstances, Jones can use the wind farms themselves to ensure that power supply matches demand: the output of a wind turbine can be changed almost instantly by angling the blades so they capture more or less wind. Computers at Xcel's building in Denver tell wind farms how much power to produce, and automated controls coördinate hundreds of turbines, changing output minute by minute if needed.

Running backup fossil-fuel plants means "throwing carbon up into the sky": "It costs money, and it's bad for the environment."

SOURCE: U.S. ENERGY INFORMATION ADMINISTRATION

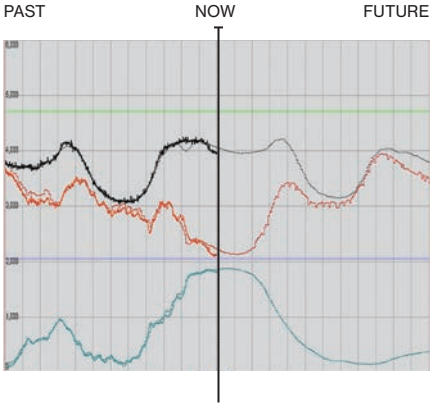
Power Forecast

Actual power output (green line) is overlaid on a three-day wind power forecast (red line). The larger the yellow shaded area, the more uncertain the forecast.



Power Balancing

The red line—the result of subtracting wind power supply (blue) from demand (black)—shows the amount of power Xcel needs to generate with its fossil-fuel plants. The lighter lines are forecasts.



Xcel's original forecasts used data from just one or two weather stations per wind farm. Now NCAR collects information from nearly every wind turbine. The data feeds into a high-resolution weather model and is combined with the output from five additional wind forecasts. Using historical data, NCAR's software learns which forecasts are best for each wind farm and assigns different weights to each accordingly. The resulting über-forecast is more accurate than any of the original ones. Then, using data about how much power each turbine in the field will generate in response to different wind speeds, NCAR tells Xcel how much power to expect, in 15-minute increments, for up to seven days.

Forecasting solar power is next for NCAR and Xcel, but that can be even trickier than wind. For one thing, Xcel doesn't get information about how much power private rooftop solar panels are generating, so it doesn't know how much of that power it could lose when clouds roll in. NCAR's new solar forecasts will use data from satellites, sky imagers, pollution monitors, and publicly owned solar panels to infer how much solar power is being generated and then predict how that amount will change.

Virtual Energy

How might extremely accurate wind and solar forecasts help us use enough renewable energy to reach climate goals of significantly reducing carbon dioxide emissions? Researchers at NREL's new Energy Systems Integration Facility start by looking at how well wind and solar power can offset each other. To what extent, for example, can wind blowing at night make up for the lack of sunshine? But they are also looking at how to couple forecasts with smart dishwashers, water heaters, solar-panel inverters, water treatment plants, and electric-car chargers, not only to accommodate shifts in the wind but to ride out inevitable windless periods and weeks of cloudy weather without resorting to fossil fuels.

Take the example of electric cars. A car stores enough electricity to power a house for anywhere from half a day to several days, depending on the size of the battery pack. And it has sophisticated power electronics that can control the timing and vary the rate of charging, which could offer a way to match fluctuating wind power to electricity demand. With small modifications, the cars' batteries can deliver stored power to a home and to the power grid. There aren't many electric cars now, but that could easily change in the decades it will take before renewable energy makes up more than 30 or 40 percent of the electricity supply (wind supplies 4 percent now, and solar less than 1 percent).

At NREL, researchers can plug 30 electric cars into docks that let them interface with power-grid simulations on a supercomputer, to project what would happen if thousands of cars were connected to the grid. The idea is that electric cars might store power from solar panels and use it to power neighborhoods when electricity demand peaks in the evening, and then recharge their batteries using wind power in the early morning hours.

Forecasts like the ones being developed at NCAR will be "absolutely critical," says Bri-Mathias Hodge, a senior research engineer at NREL. They will help determine when the cars' batteries should charge to maximize the electricity they make available to the grid without leaving drivers short of the power they need.

Even before that becomes a reality, though, forecasts from NCAR are already having a big effect. Last year, on a windy weekend when power demand was low, Xcel set a record: during one hour, 60 percent of its electricity for Colorado was coming from the wind. "That kind of wind penetration would have given dispatchers a heart attack a few years ago," says Drake Bartlett, who heads renewable-energy integration for Xcel. Back then, he notes, they wouldn't have known whether they might suddenly lose all that power. "Now we're taking it in stride," he says. "And that record is going to fall."

SOURCE: XCEL ENERGY

MIT Technology Review

Di Su

Innovations and Ideas Fueling Our Connected World

June 9–10, 2014
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Speakers include:

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Director, User Experience Research, Intel Labs
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Mike Schroepfer
CTO, Facebook
Insights into building a social infrastructure for billions, from providing global access to creating new experiences through deep learning

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Breakthrough
High-quality virtual-reality hardware that is cheap enough for the consumer market.

Why It Matters
Visually immersive interfaces will lead to new forms of entertainment and communications.

Key Players
- Oculus VR
- Sony
- Vuzix
- Nvidia

Oculus Rift

Thirty years after virtual-reality goggles and immersive virtual worlds made their debut, the technology finally seems poised for widespread use.

BY
Simon Parkin

PALMER LUCKEY HAD NOT BEEN BORN when *The Lawnmower Man* was released in 1992, but the movie, with its vision of computer-generated sensory immersion, helped seed his interest in virtual reality as soon as he saw it. He dreamed of playing video games in simulated 3-D worlds—a dream that led him to amass one of the world's largest collections of head-mounted displays and, eventually, inspired him to attempt to make his own. With no formal engineering training, Luckey designed his first working prototype in his garage at the age of 16.

Today, the 21-year-old is the founder of Oculus VR, a company that is on the verge of releasing the Rift, an affordable virtual-reality headset for playing ultra-immersive video games. Facebook bought the company for $2 billion this spring.

Oculus VR had already attracted more than $91 million in venture funding, a near-fanatical following, and team members like the game programmer John Carmack, who led the development of influential video games such as Doom, Quake, and Rage. But the Facebook deal is a sign of faith that virtual reality is now sharp enough and cheap enough to have huge potential for more than video games. The idea of merging immersive virtual reality with social communications is intriguing. It could also be a compelling tool for teleconferencing, online shopping, or more passive forms of entertainment. Some filmmakers are, in fact, already experimenting with movies designed just for the Rift.

Virtual-reality headsets could be found in some arcades when *The Lawn-*

Opposite:
A version of the Oculus Rift headset was made available to developers last year.

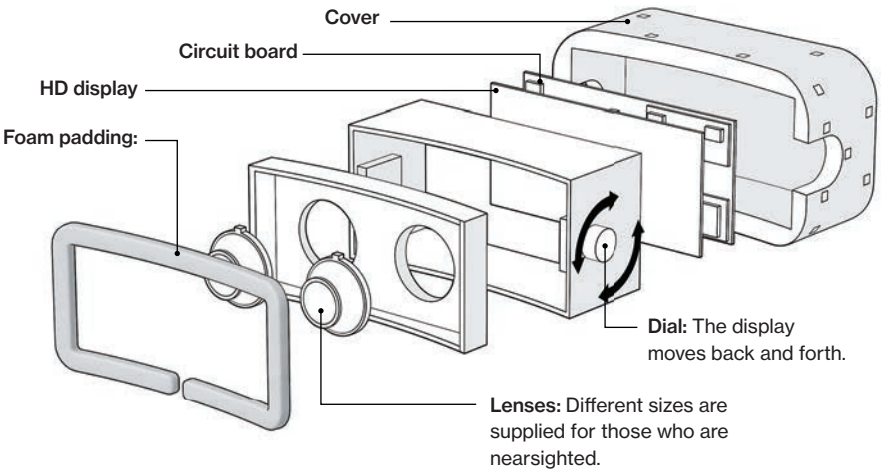
MODEL: JJ BANICKI

Bruce Peterson

Inside View

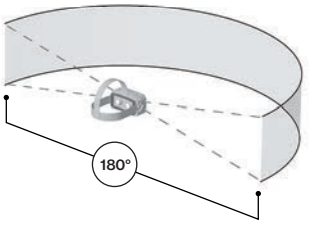
Oculus VR's first commercial headset was built using just a few components, including off-the-shelf electronics and simple lenses.

THE BUILD



THE VIEW

Software turns a scene into two warped side-by-side views. Looking through the device's lenses, the wearer sees an expansive 3-D panorama (right).



mower Man was in the theaters. But the technology wasn't good enough to catch on widely. This time around, Luckey realized that cheap smartphone components could be combined to stunning effect, rendering bright, crisp worlds much more compelling than the blocky graphics often seen through earlier virtual-reality headsets.

When you use the Rift, you feel as though you're actually inside these worlds. The technology follows the movement of your head in real time; lean in to take a better look at a virtual flower or look to the skies to gaze at a virtual cloud, and your mind is drawn into the simulation. You can almost believe you are fully there.

The vast audience for home video games appears hungry for the device. In August 2012, Oculus VR set out to raise $250,000 on Kickstarter and met the goal in a matter of hours. It surpassed $1 million within two days.

Luckey started shipping a version of the Rift for software developers in March 2013 for just $300, and in the past year, the hardware has improved significantly. The retail version, which is expected to launch later this year or early next, will offer resolution higher than 1,920 by 1,080 pixels per eye. Such stunningly sharp definition has only recently become possible at such a low price.

While video games are where this improved virtual-reality technology is likely to take off first, it could also have applications in telepresence, architecture, computer-aided design, emergency response training, and phobia therapy.

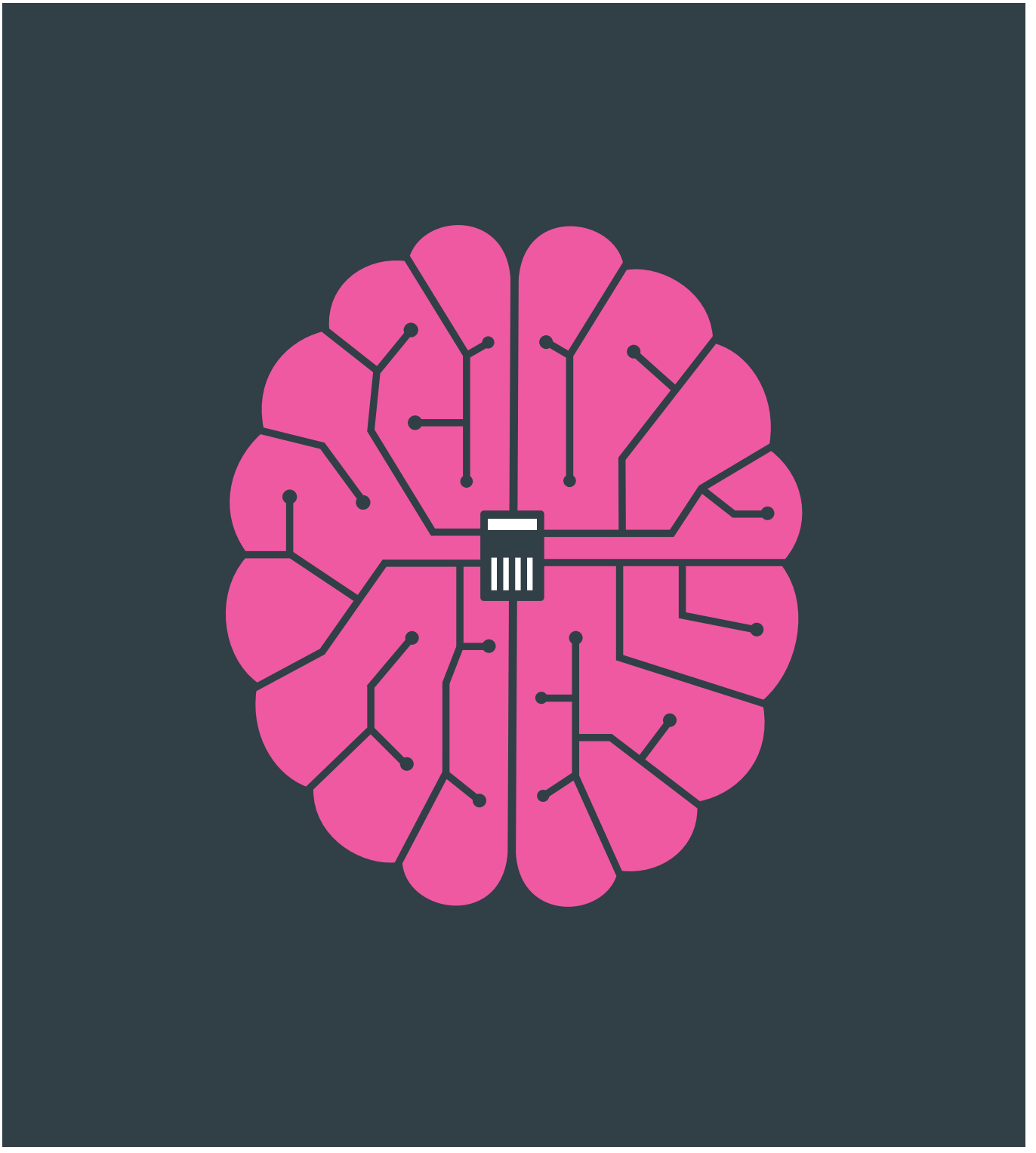
Indeed, in some niches, older VR technology has been in use for years. Some surgeons routinely practice operations using VR simulations, while some industrial designers use the technology to view their designs as if they had already been constructed. But 30 years ago, when Jaron Lanier founded VPL Research, the first company to sell virtual-reality goggles, such products were too expensive for the consumer mainstream (a single head-mounted display cost as much as $100,000).

There were other reasons, too, that earlier versions of virtual reality failed commercially. Players of Nintendo's Virtual Boy, a low-end VR game system launched in the mid-1990s, complained of nausea after extended play. For other players, the keen sense of wonder and presence they felt inside a virtual world soon dissipated. "Your first time playing a game in a virtual world is incredible," Lanier says, "but the 20th time is wearying."

Things may be different now. Though some testers have experienced nausea using the Oculus Rift, the company says the latest version has almost eliminated this problem. And today's virtual environments offer so much more fidelity that they could remain captivating for much longer. Artists have been able to create a more stimulating range of worlds, from the rigorously realistic to the more abstract and painterly.

Already Oculus has inspired imitators. Acknowledging the Rift as an inspiration, Sony has demonstrated a VR headset that players will be able to use with the PlayStation 4. Sony is also working with NASA to create a virtual-reality simulation of Mars using images pulled from the Mars Rover. A more mundane but potentially useful application that Sony is exploring would let travelers visit virtual hotel rooms before booking the real thing. Assuming they ever want to take the headsets off. T

JOHN MACNEILL; SOURCES: OCULUS RIFT, IFIXIT.COM



Noma Bar

Microprocessors configured more like brains than traditional chips could soon make computers far more astute about what's going on around them.

BY
Robert D. Hof

Neuromorphic Chips

Breakthrough
An alternative design for computer chips that will enhance artificial intelligence.

Why It Matters
Traditional chips are reaching fundamental performance limits.

Key Players
- Qualcomm
- IBM
- HRL Laboratories
- Human Brain Project

A PUG-SIZE ROBOT NAMED PIONEER slowly rolls up to the Captain America action figure on the carpet. They're facing off inside a rough model of a child's bedroom that the wireless-chip maker Qualcomm has set up in a trailer. The robot pauses, almost as if it is evaluating the situation, and then corrals the figure with a snowplow-like implement mounted in front, turns around, and pushes it toward three squat pillars representing toy bins. Qualcomm senior engineer Ilwoo Chang sweeps both arms toward the pillar where the toy should be deposited. Pioneer spots that gesture with its camera and dutifully complies. Then it rolls back and spies another action figure, Spider-Man. This time Pioneer beelines for the toy, ignoring a chessboard nearby, and delivers it to the same pillar with no human guidance.

This demonstration at Qualcomm's headquarters in San Diego looks modest, but it's a glimpse of the future of computing. The robot is performing tasks that have typically needed powerful, specially programmed computers that use far more electricity. Powered by only a smartphone chip with specialized software, Pioneer can recognize objects it hasn't seen before, sort them by their similarity to related objects, and navigate the room to deliver them to the right location—not because of laborious programming but merely by being shown once where they should go. The robot can do all that because it is simulating, albeit in a very limited fashion, the way a brain works.

Later this year, Qualcomm will begin to reveal how the technology can be embedded into the silicon chips that power every manner of electronic device. These "neuromorphic" chips—so named because they are modeled on biological brains—will be designed to process sensory data such as images and sound and to respond to changes in that data in ways not specifically programmed. They promise to accelerate decades of fitful progress in artificial intelligence and lead to machines that are able to understand and interact with the world in human-like ways. Medical sensors and devices could track individuals' vital signs and response to treatments over time, learning to adjust dosages or even catch problems early. Your smartphone could learn to anticipate what you want next, such as background on someone you're about to meet or an alert that it's time to leave for your next meeting. Those self-driving cars Google is experimenting with might not need your help at all, and more adept Roombas wouldn't get stuck under your couch. "We're blurring the boundary between silicon and biological systems," says Qualcomm's chief technology officer, Matthew Grob.

Qualcomm's chips won't become available until next year at the earliest; the company will spend 2014 signing up researchers to try out the technology. But if it delivers, the project—known as the Zeroth program—would be the first large-scale commercial platform for neuromorphic computing. That's on top of promising efforts at universities and at corporate labs such as IBM Research and HRL Laboratories, which have each developed neuromorphic chips under a $100 million project for the Defense Advanced Research Projects Agency.

Likewise, the Human Brain Project in Europe is spending roughly 100 million euros on neuromorphic projects, including efforts at Heidelberg University and the University of Manchester. Another group in Germany recently reported using a neuromorphic chip and software modeled on insects' odor-processing systems to recognize plant species by their flowers.

Today's computers all use the so-called von Neumann architecture, which shuttles data back and forth between a central processor and memory chips in linear sequences of calculations. That method is great for crunching numbers and executing precisely written programs, but not for processing images or sound and making sense of it all. It's telling that in 2012, when Google demonstrated artificial-intelligence software that learned to recognize cats in videos without being told what a cat was, it needed 16,000 processors to pull it off.

Continuing to improve the performance of such processors requires their manufacturers to pack in ever more, ever faster transistors, silicon memory caches, and data pathways, but the sheer heat generated by all those components is limiting how fast chips can be operated, especially in power-stingy mobile devices. That could halt progress toward devices that effectively process images, sound, and other sensory information and then apply it to tasks such as face recognition and robot or vehicle navigation.

No one is more acutely interested in getting around those physical challenges than Qualcomm, maker of wireless chips used in many phones and tablets. Increasingly, users of mobile devices are demanding more from these machines. But today's personal-assistant services, such as Apple's Siri and Google Now, are limited because they must call out to the cloud for more powerful computers to answer or anticipate queries. "We're running up against walls," says Jeff Gehlhaar, the Qualcomm vice president of technology who heads the Zeroth engineering team.

Neuromorphic chips attempt to model in silicon the massively parallel way the brain processes information as billions of neurons and trillions of synapses respond to sensory inputs such as visual and auditory stimuli. Those neurons also change how they connect with each other in response to changing images, sounds, and the like. That is the process we call learning. The chips, which incorporate brain-inspired models called neural networks, do the same. That's why Qualcomm's robot—even though for now it's merely running software that simulates a neuromorphic chip—can put Spider-Man in the same location as Captain America without having seen Spider-Man before.

Qualcomm could add a "neural processing unit" to mobile-phone chips to handle sensory data and tasks such as image recognition.

Even if neuromorphic chips are nowhere near as capable as the brain, they should be much faster than current computers at processing sensory data and learning from it. Trying to emulate the brain just by using special software on conventional processors—the way Google did in its cat experiment—is way too inefficient to be the basis of machines with still greater intelligence, says Jeff Hawkins, a leading thinker on AI who created the Palm Pilot before cofounding Numenta, a maker of brain-inspired software. "There's no way you can build it [only] in software," he says of effective AI. "You have to build this in silicon."

Neural Channel

As smartphones have taken off, so has Qualcomm, whose market capitalization now tops Intel's. That's thanks in part to the hundreds of wireless-communications patents that Qualcomm shows off on two levels of a seven-story atrium lobby at its San Diego headquarters. Now it's looking to break new ground again. First in coöperation with Brain Corp., a neuroscience startup it invested in and that is housed at its headquarters, and more recently with its own growing staff, it has been quietly working for the past five years on algorithms to mimic brain functions as well as hardware to execute them. The Zeroth project has initially focused on robotics applications because the way robots can interact with the real world provides broader lessons about how the brain learns—lessons that can then be applied in smartphones and other products. Its name comes from Isaac Asimov's "Zeroth Law" of robotics: "A robot may not harm humanity, or, by inaction, allow humanity to come to harm."

The idea of neuromorphic chips dates back decades. Carver Mead, the Caltech professor emeritus who is a legend in integrated-circuit design, coined the term in a 1990 paper, describing how analog chips—those that vary in their output, like real-world phenomena, in contrast to the binary, on-or-off nature of digital chips—could mimic the electrical activity of neurons and synapses in the brain. But he struggled to find ways to reliably build his analog chip designs. Only one arguably neuromorphic processor, a noise suppression chip made by Audience, has sold in the hundreds of millions. The chip, which is based on the human cochlea, has

Processing Powers

	What they do well	What they're good for
Neuromorphic chips	Detect and predict patterns in complex data, using relatively little electricity	Applications that are rich in visual or auditory data and that require a machine to adjust its behavior as it interacts with the world
Traditional chips (von Neumann architecture)	Reliably make precise calculations	Anything that can be reduced to a numerical problem, although more complex problems require substantial amounts of power

been used in phones from Apple, Samsung, and others.

As a commercial company, Qualcomm has opted for pragmatism over sheer performance in its design. That means the neuromorphic chips it's developing are still digital chips, which are more predictable and easier to manufacture than analog ones. And instead of modeling the chips as closely as possible on actual brain biology, Qualcomm's project emulates aspects of the brain's behavior. For instance, the chips encode and transmit data in a way that mimics the electrical spikes generated in the brain as it responds to sensory information. "Even with this digital representation, we can reproduce a huge range of behaviors we see in biology," says M. Anthony Lewis, the project engineer for Zeroth.

The chips would fit neatly into the existing business of Qualcomm, which dominates the market for mobile-phone chips but has seen revenue growth slow. Its Snapdragon mobile-phone chips include components such as graphics processing units; Qualcomm could add a "neural processing unit" to the chips to handle sensory data and tasks such as image recognition and robot navigation. And given that Qualcomm has a highly profitable business of licensing technologies to other companies, it would be in a position to sell the rights to use algorithms that run on neuromorphic chips. That could lead to sensor chips for vision, motion control, and other applications.

Cognitive Companion

Matthew Grob was startled, then annoyed, when he heard the theme to *Sanford and Son* start playing in the middle of a recent meeting. It turns out that on a recent trip to Spain, he had set his smartphone to issue a reminder using the tune as an alarm, and the phone thought it was time to play it again. That's just one small example of how far our personal devices are from being intelligent. Grob dreams of a future when instead of monkeying with the settings of his misbehaving phone, as he did that day, all he would have to do is bark, "Don't do that!" Then the phone might learn that it should switch off the alarm when he's in a new time zone.

Qualcomm is especially interested in the possibility that neuromorphic chips could transform smartphones and other mobile devices into cognitive companions that pay attention to your actions and surroundings and learn your habits over time. "If you and your device can perceive the environment in the same way, your device will be better able to understand your intentions and anticipate your needs," says Samir Kumar, a business development director at Qualcomm's research lab.

Pressed for examples, Kumar ticks off a litany: If you tag your dog in a photo, your phone's camera would recognize the pet in every subsequent photo. At a soccer game, you could tell the phone to snap a photo only when your child is near the goal. At bedtime, it would know without your telling it to send calls to voice mail. In short, says Grob, your smartphone would have a digital sixth sense.

Qualcomm executives are reluctant to embark on too many flights of fancy before their chip is even available. But neuromorphic researchers elsewhere don't mind speculating. According to Dharmendra Modha, a top IBM researcher in San Jose, such chips might lead to glasses for the blind that use visual and auditory sensors to recognize objects and provide audio cues; health-care systems that monitor vital signs, provide early warnings of potential problems, and suggest ways to individualize treatments; and computers that draw on wind patterns, tides, and other indicators to predict tsunamis more accurately. At HRL this summer, principal research scientist Narayan Srinivasa plans to test a neuromorphic chip in a bird-size device from AeroVironment that will be flown around a couple of rooms. It will take in data from cameras and other sensors so it can remember which room it's in and learn to navigate that space more adeptly, which could lead to more capable drones.

It will take programmers time to figure out the best way to exploit the hardware. "It's not too early for hardware companies to do research," says Dileep George, cofounder of the artificial-intelligence startup Vicarious. "The commercial products could take a while." Qualcomm executives don't disagree. But they're betting that the technology they expect to launch this year will bring those products a lot closer to reality.

RC Rivera

Relatively cheap drones with advanced sensors and imaging capabilities are giving farmers new ways to increase yields and reduce crop damage.

BY
Chris Anderson

A drone from 3D Robotics flies over the fields at Kunde Family Vineyard.

Agricultural Drones

RYAN KUNDE IS A WINEMAKER WHOSE family's picture-perfect vineyard nestles in the Sonoma Valley north of San Francisco. But Kunde is not your average farmer. He's also a drone operator—and he's not alone. He's part of the vanguard of farmers who are using what was once military aviation technology to grow better grapes using pictures from the air, part of a broader trend of using sensors and robotics to bring big data to precision agriculture.

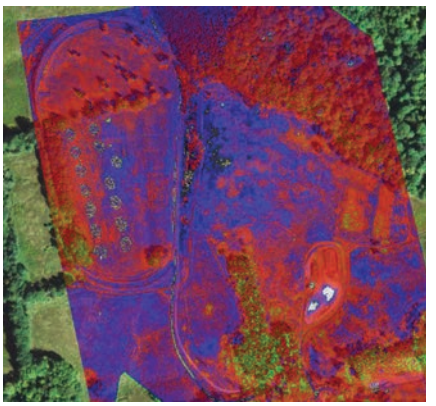
What "drones" means to Kunde and the growing number of farmers like him is simply a low-cost aerial camera platform: either miniature fixed-wing airplanes or, more commonly, quadcopters and other multibladed small helicopters. These aircraft are equipped with an autopilot using GPS and a standard point-and-shoot cam-

Breakthrough
Easy-to-use agricultural drones equipped with cameras, for less than $1,000.

Why It Matters
Close monitoring of crops could improve water use and pest management.

Key Players
- 3D Robotics
- Yamaha
- PrecisionHawk

A drone from PrecisionHawk is equipped with multiple sensors to image fields.



This image depicts vegetation in near-infrared light to show chlorophyll levels.

era controlled by the autopilot; software on the ground can stitch aerial shots into a high-resolution mosaic map. Whereas a traditional radio-controlled aircraft needs to be flown by a pilot on the ground, in Kunde's drone the autopilot (made by my company, 3D Robotics) does all the flying, from auto takeoff to landing. Its software plans the flight path, aiming for maximum coverage of the vineyards, and controls the camera to optimize the images for later analysis.

This low-altitude view (from a few meters above the plants to around 120 meters, which is the regulatory ceiling in the United States for unmanned aircraft operating without special clearance from the Federal Aviation Administration) gives a perspective that farmers have rarely had before. Compared with satellite imagery, it's much cheaper and offers higher resolution. Because it's taken under the clouds, it's unobstructed and available anytime. It's also much cheaper than crop imaging with a manned aircraft, which can run $1,000 an hour. Farmers can buy the drones outright for less than $1,000 each.

The advent of drones this small, cheap, and easy to use is due largely to remarkable advances in technology: tiny MEMS sensors (accelerometers, gyros, magnetometers, and often pressure sensors), small GPS modules, incredibly powerful processors, and a range of digital radios. All those components are now getting better and cheaper at an unprecedented rate, thanks to their use in smartphones and the extraordinary economies of scale of that industry. At the heart of a drone, the autopilot runs specialized software—often open-source programs created by communities such as DIY Drones, which I founded, rather than costly code from the aerospace industry.

Drones can provide farmers with three types of detailed views. First, seeing a crop from the air can reveal patterns that expose everything from irrigation problems to soil variation and even pest and fungal infestations that aren't apparent at eye level. Second, airborne cameras can take multispectral images, capturing data from the infrared as well as the visual spectrum, which can be combined to create a view of the crop that highlights differences between healthy and distressed plants in a way that can't be seen with the naked eye. Finally, a drone can survey a crop every week, every day, or even every hour. Combined to create a time-series animation, that imagery can show changes in the crop, revealing trouble spots or opportunities for better crop management.

It's part of a trend toward increasingly data-driven agriculture. Farms today are bursting with engineering marvels, the result of years of automation and other innovations designed to grow more food with less labor. Tractors autonomously plant seeds within a few centimeters of their target locations, and GPS-guided harvesters reap the crops with equal accuracy. Extensive wireless networks backhaul data on soil hydration and environmental factors to faraway servers for analysis.

But what if we could add to these capabilities the ability to more comprehensively assess the water content of soil, become more rigorous in our ability to spot irrigation and pest problems, and get a general sense of the state of the farm, every day or even every hour? The implications cannot be stressed enough. We expect 9.6 billion people to call Earth home by 2050. All of them need to be fed. Farming is an input-output problem. If we can reduce the inputs—water and pesticides—and maintain the same output, we will be overcoming a central challenge.

Agricultural drones are becoming a tool like any other consumer device, and we're starting to talk about what we can do with them. Ryan Kunde wants to irrigate less, use less pesticide, and ultimately produce better wine. More and better data can reduce water use and lower the chemical load in our environment and our food. Seen this way, what started as a military technology may end up better known as a green-tech tool, and our kids will grow up used to flying robots buzzing over farms like tiny crop dusters. T

Chris Anderson, the former editor in chief of Wired*, is the cofounder and CEO of 3D Robotics and founder of DIY Drones.*

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Brain Mapping

A new map, a decade in the works, shows neural structures in far greater detail than ever before, providing neuroscientists with a guide to the brain's immense complexity.

BY
Courtney Humphries

NEUROSCIENTISTS HAVE MADE REMARKABLE PROGRESS IN recent years toward understanding how the brain works. And in coming years, Europe's Human Brain Project will attempt to create a computational simulation of the human brain, while the U.S. BRAIN Initiative will try to create a wide-ranging picture of brain activity. These ambitious projects will greatly benefit from a new resource: detailed and comprehensive maps of the brain's structure and its different regions.

Opposite: A section of the human brain map created by a team of international researchers shows details as small as 20 micrometers.

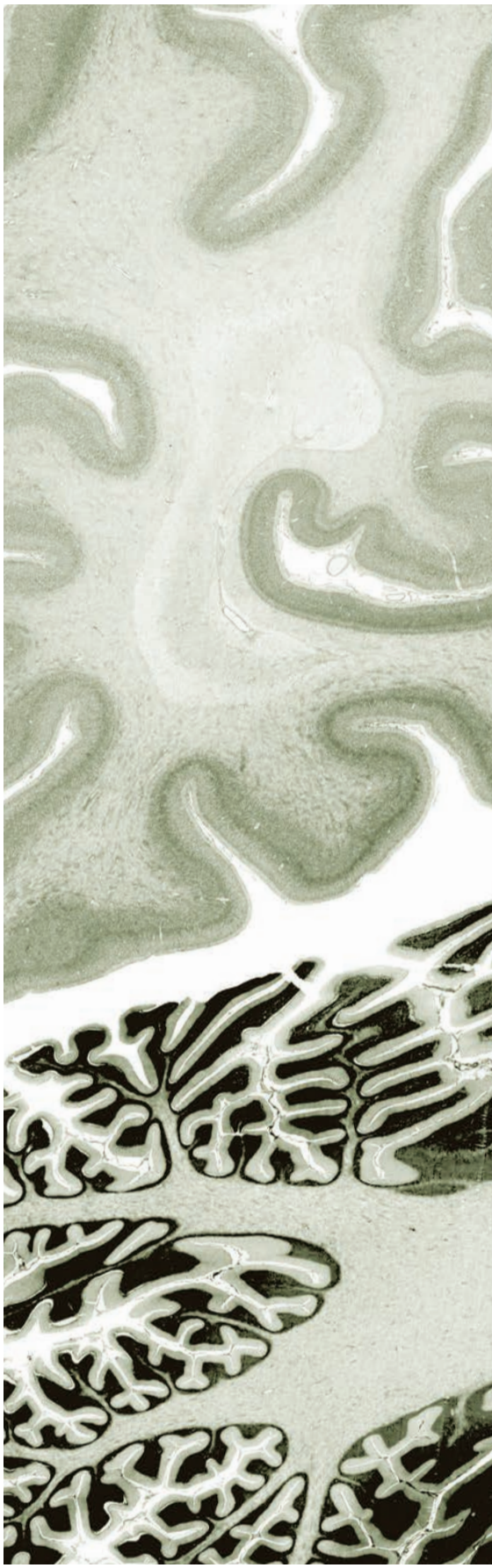
As part of the Human Brain Project, an international team of researchers led by German and Canadian scientists has produced a three-dimensional atlas of the brain that has 50 times the resolution of previous such maps. The atlas, which took a decade to complete, required slicing a brain into thousands of thin sections and digitally stitching them back together with the help of supercomputers. Able to show details as small as 20 micrometers, roughly the size of many human cells, it is a major step forward in understanding the brain's three-dimensional anatomy.

To guide the brain's digital reconstruction, researchers led by Katrin Amunts at the Jülich Research Centre in Germany initially used an MRI machine to image the postmortem brain of a 65-year-old woman. The brain was then cut into ultrathin slices. The scientists stained the sections and then imaged them one by one on a flatbed scanner. Alan Evans and his coworkers at the Montreal Neurological Institute organized the 7,404 resulting

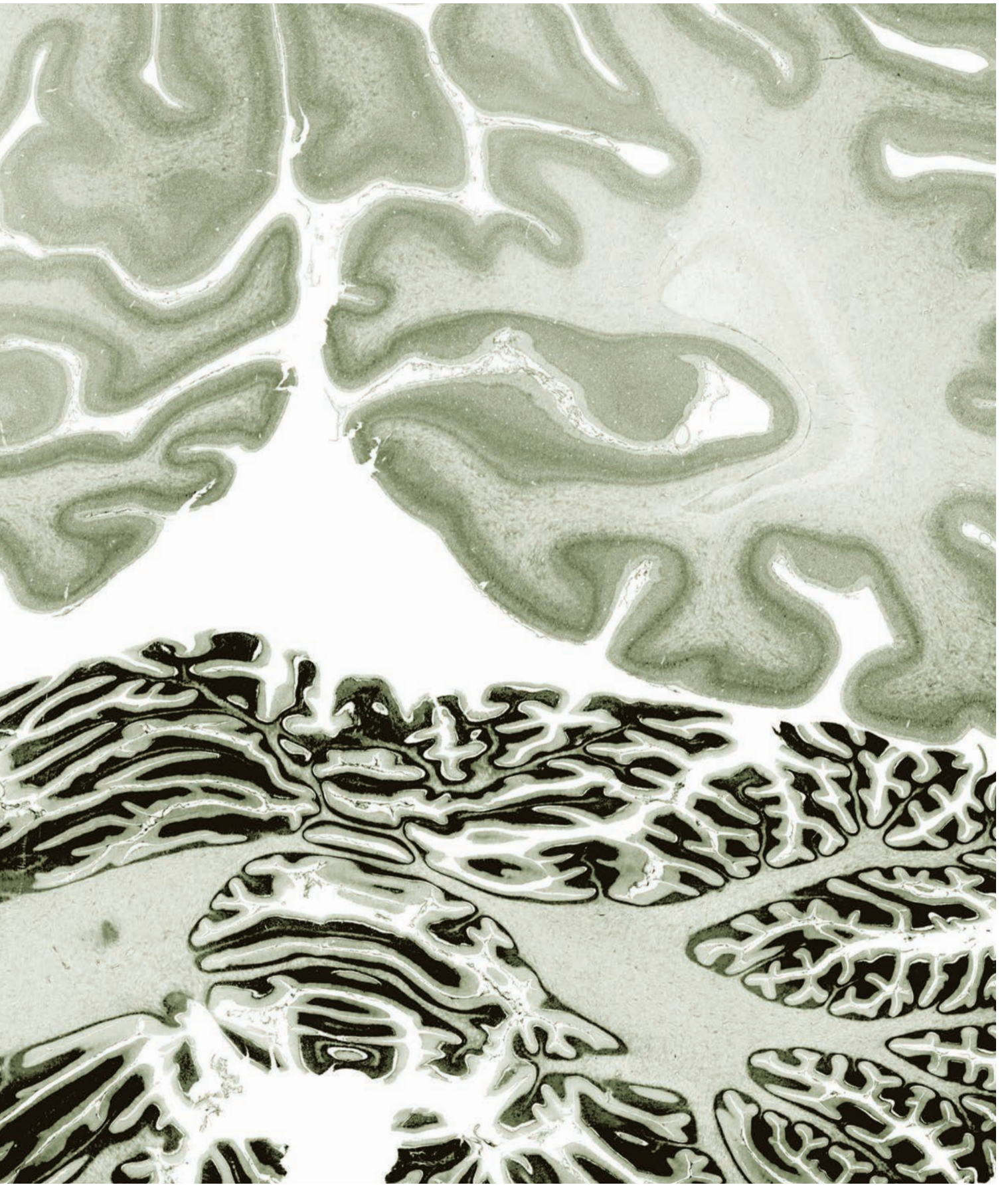
Breakthrough
A high-resolution map that shows structures of the human brain as small as 20 micrometers.

Why It Matters
As neuroscientists try to understand how the brain works, they need a detailed map of its anatomy.

Key Players
- Katrin Amunts, Jülich Research Centre
- Alan Evans, Montreal Neurological Institute
- Karl Deisseroth, Stanford University



COURTESY OF BRAIN IMAGING CENTER/MONTREAL NEUROLOGICAL INSTITUTE



images into a data set about a terabyte in size. Slicing had bent, ripped, and torn the tissue, so Evans had to correct these defects in the images. He also aligned each one to its original position in the brain. The result is mesmerizing: a brain model that you can swim through, zooming in or out to see the arrangement of cells and tissues.

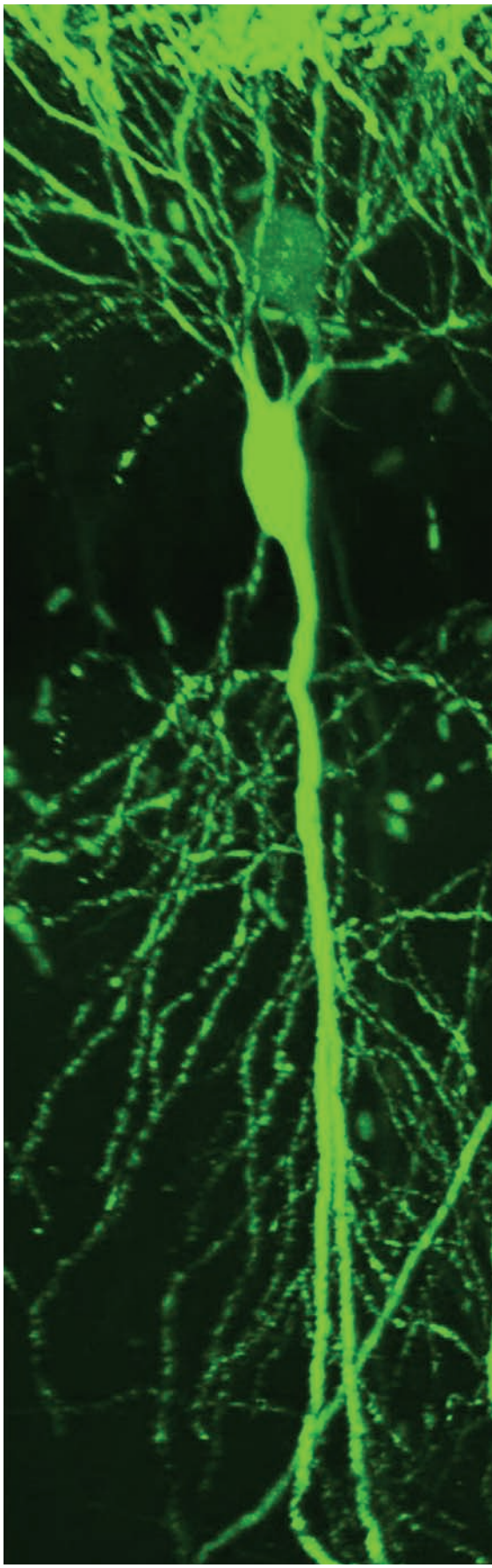
At the start of the 20th century, a German neuroanatomist named Korbinian Brodmann parceled the human cortex into nearly 50 different areas by looking at the structure and organization of sections of brain under a microscope. "That has been pretty much the reference framework that we've used for 100 years," Evans says. Now he and his coworkers are redoing Brodmann's work as they map the borders between brain regions. The result may show something more like 100 to 200 distinct areas, providing scientists with a far more accurate road map for studying the brain's different functions.

"We would like to have in the future a reference brain that shows true cellular resolution," says Amunts—about one or two micrometers, as opposed to 20. That's a daunting goal, for several reasons. One is computational: Evans says such a map of the brain might contain several petabytes of data, which computers today can't easily navigate in real time, though he's optimistic that they will be able to in the future. Another problem is physical: a brain can be sliced only so thin.

Opposite: A new technique developed at Stanford, called Clarity, provides an image of the neurons and circuitry in a mouse's brain.

Advances could come from new techniques that allow scientists to see the arrangement of cells and nerve fibers inside intact brain tissue at very high resolution. Amunts is developing one such technique, which uses polarized light to reconstruct three-dimensional structures of nerve fibers in brain tissue. And a technique called Clarity, developed in the lab of Karl Deisseroth, a neuroscientist and bioengineer at Stanford University, allows scientists to directly see the structures of neurons and circuitry in an intact brain. The brain, like any other tissue, is usually opaque because the fats in its cells block light. Clarity melts the lipids away, replacing them with a gel-like substance that leaves other structures intact and visible.

Though Clarity can be used on a whole mouse brain, the human brain is too big to be studied fully intact with the existing version of the technology. But Deisseroth says the technique can already be used on blocks of human brain tissue thousands of times larger than a thin brain section, making 3-D reconstruction easier and less error prone. And Evans says that while Clarity and polarized-light imaging currently give fantastic resolution to pieces of brain, "in the future we hope that this can be expanded to include a whole human brain."



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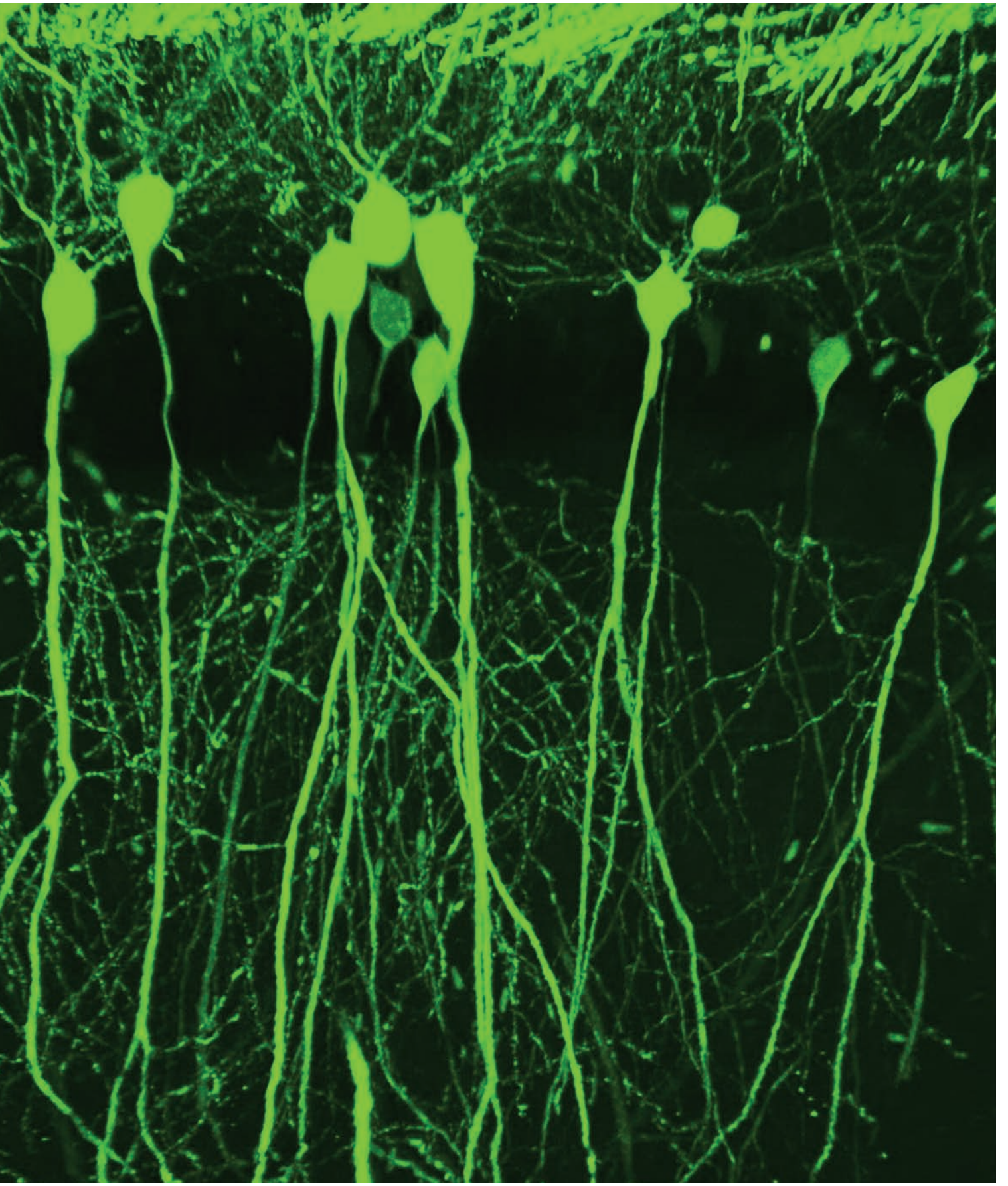

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BUSINESS REPORT

Spies, Technology, and Business

How the NSA eavesdropping scandal could balkanize the Internet or make it safer.

CONTENTS

Find additional material for this report at technologyreview.com/business

DANIEL ZENDER

The Big Question

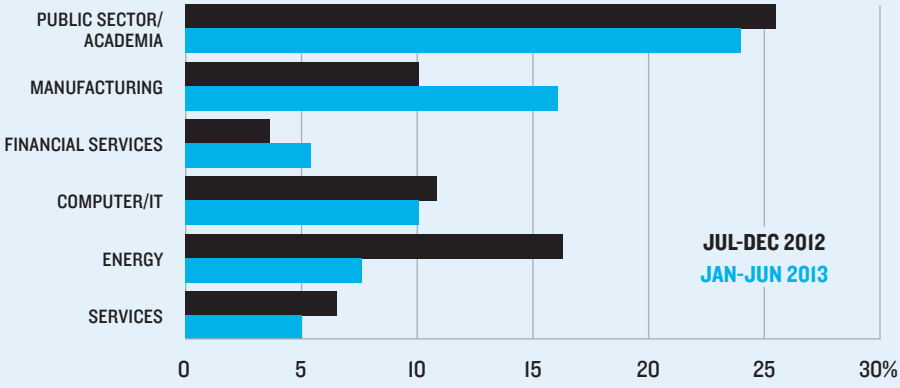
Spying Is Bad for Business

Can we trust an Internet that's become a weapon of governments?

● Following a one-day summit in Brasilia this February, negotiators from Brazil and Europe reached a deal to lay a $185 million fiber-optic cable spanning the 3,476 miles between Fortaleza and Lisbon. The cable will be built by a consortium of Spanish and Brazilian companies. According to Brazil's president, Dilma Rousseff, it will "protect freedom." No longer will South America's Internet traffic get routed through Miami, where American spies might see it.

She's not being paranoid. Documents leaked last June by former U.S. intelligence contractor Edward Snowden revealed a global surveillance operation coördinated by the U.S. National Security Agency and its counterpart in Britain, the GCHQ. Among the hundreds of millions of alleged targets of the dragnet: Brazil's state oil company, Petrobras, as well as Rousseff's own cell phone. →

Top Targets of Cyberattacks



The big question in this *MIT Technology Review* business report is how the Snowden revelations are affecting the technology business. Some of the consequences are already visible. Consumers are favoring anonymous apps. Large Internet companies, like Google, have raced to encrypt all their communications. In Germany, legislators are discussing an all-European communications grid.

Eugene Kaspersky, founder of the Moscow-based antivirus company that bears his name, warns that the Internet is fracturing. His view is that Brazil's new cable is akin to China's Great Firewall (that country's system for censoring Web results), or calls by nationalists in Russia to block Skype, or an unfolding German plan to keep e-mail traffic within its borders. Nations are limiting access to their networks. Kaspersky's company predicts that this could lead to "the collapse of the current Internet, which will break into dozens of national networks."

Analysts including Forrester Research predict billions in losses for U.S. Internet services such as Dropbox and Amazon because of suspicion from technology consumers, particularly in Europe, in the wake of Snowden's revelations. "The Snowden leaks have painted a U.S.-centric Internet infrastructure, and now people are looking for alternatives," says James Lewis, director of the strategic technologies program at the Center for Strategic and International Studies in Washington, D.C.

Many nations eavesdrop, each for their own reasons. Some target dissidents with malware to watch their keystrokes. Others, like China, also bleed companies of intellectual secrets about jet fighters and wind turbines. So pervasive and successful has digital espionage become that in 2012, Keith Alexander, the Army general in charge of the NSA, described it as "the greatest transfer of wealth in history." He estimated that U.S. companies lose $250 billion a year to intellectual-property theft.

The Snowden leaks painted a picture of a U.S.-centric Internet. Now people are looking for alternatives.

This is hastening the trend to secure networks, to isolate them, or even to disconnect. In this report, we visit a small energy company for which a network cable might as well be Medusa's hair. The company is so frightened that it keeps its best ideas on computers quarantined from the Internet. Retrograde technology is winning money and resources. Following the Snowden revelations, Russia's secret service placed an order for $15,000 worth of typewriters and ribbons. They said paper was safest for some presidential documents.

Security experts have been warning for some time that computer networks are not secure from intruders. But in 2013, we learned that the mayhem has become strategic. Governments now write computer viruses. And if they can't, they can purchase them. A half-dozen boutique R&D houses, like Italy's Hacking Team, develop computer vulnerabilities and openly market them to government attackers.

Criminals use common computer weaknesses to infect as many machines as possible. But governments assemble large research teams and spend millions patiently pursuing narrow objectives. Costin Raiu, a Kaspersky researcher who investigates such "advanced persistent threats," says he logs on to his computer assuming he is not alone. "I operate under the principle that my computer is owned by at least three governments," he says.

That is a threat mainstream technology companies are grappling with. The U.S. government circumvented Google's security measures and secretly collected customer data. British spies scooped up millions of webcam images from Yahoo. In December, on Microsoft's official blog, the company's top lawyer, Brad Smith, said he had reason to view surreptitious "government snooping" as no different from criminal malware. Microsoft, along with Google and Yahoo, has responded by greatly widening its use of encryption.

"We're living in a very interesting time, where companies are becoming unwilling pawns in cyberwarfare," says Menny Barzilay, a former Israeli intelligence officer now working in IT security for the Bank Hapoalim Group, in Tel Aviv. In this new context, nobody can say where the responsibilities of a company may end and those of a nation might begin. Should a commercial bank be expected to expend resources to defend itself when its attacker is a country? "This is not a 'maybe' situation. This is happening right now," says Barzilay. "And this is just the beginning."

If the Internet and its components cannot be trusted, how will that affect business? Consider the case of Huawei, the Chinese company that last year became the world's largest seller of telecom equipment. Its U.S. market share is paltry, because the

SOURCE: SYMANTEC

government has long claimed that Huawei's gear is a Trojan horse for China's intelligence services. Now American firms like Cisco Systems say their Chinese customers are turning away for similar reasons. After all, the Snowden documents suggest how vigorously the NSA worked to insert back doors in gear, software, and undersea cables—in some cases via what the agency called "sensitive, cooperative relationships with specific industry partners" identified by code names.

Mistrust is also creating business opportunities. In this issue we travel to an old bunker in Switzerland that local entrepreneurs have turned into a server farm, hoping to do for data what the Swiss once did for Nazi gold and billionaires' bank accounts. Thanks to its privacy laws and discreet culture, the country is emerging as a hub for advanced security technology. In Lewis's view, these sorts of technological initiatives threaten the American lead in Internet services such as remote data storage. "It hasn't been long enough to know if the economic effects are trivial or serious, but the emergence of foreign competitors is a sign that it's serious," he says.

There's even a shift under way in consumer technology. Consumers have been rushing to download texting apps like Snapchat, where messages disappear. They are posting on anonymous message boards like Whispr and buying "cryptophones" that scramble their calls. Spy-shop stuff is going mainstream. Phil Zimmerman, a famous privacy advocate, helped create one of the cryptophones, the $629 Blackphone, launched in February at the big mobile communications conference in Barcelona, Spain.

That is how Edward Snowden is affecting business. People are asking questions about technology products, and technology companies, that they never asked before. Is it safe to connect? Are you Russian or American? "This is something that changed since last June, when the leaks started," says Mikko Hypponen, chief research officer of the Finnish security company F-Secure. "Before, the idea was that the Web had no borders, no countries. This was the naïve utopia. Now we have woken up." *—Antonio Regalado*

Emerged Technologies

Cyberspying Targets Energy Secrets

Intruders seek data on oil deposits, cutting-edge technology.

● Take a tour of 1366 Technologies, a startup near Boston that is developing a cheaper way to make solar cells, and you will see open spaces with low cubicles, engineers at their desks, a machine shop, and testing equipment running silicon wafers through their paces.

But the tour is a bluff: it's what you don't see that's really interesting. In another part of the building—one with no obvious way in—sit the engineers working on the core technology, machines that could cut the cost of silicon wafers for solar cells in half. Perhaps most important, computers used for the real work are entirely cut off from the Internet.

"We are paranoid," 1366 CEO Frank van Mierlo says. "We've taken our entire engineering server offline and air-gapped it, like the Department of Defense."

There has recently been much talk in Washington about the need to guard critical infrastructure, such as power plants, against possible enemy cyberattacks. But energy companies say that their key inventions and business data are already the target of increasingly sophisticated cyber-espionage.

"[It] quietly kept getting worse and worse," Dana Deasy, the former chief information officer of BP, said last November during a meeting of information technology executives in Barcelona, Spain. "You finally wake up one day and you're sitting in a world where this is a serious threat to the industry as a whole."

Attacks can go unnoticed for years, or are never reported. As a result, estimates of stolen intellectual property vary "so widely as to be meaningless," according to a 2011 report on foreign cyberspying by the U.S. Director of National Intelligence, which cited calculations of between $2 billion and $400 billion a year.

Companies say they worry most about state-sponsored attacks, which tend to be "incredibly well organized, incredibly sophisticated," according to BP's Deasy.

$800 million
Spying damage to one U.S. company

Some of the hackers are looking for proprietary data about oil fields, painstakingly gathered using costly seismic surveys, which underpins a business worth $3 trillion a year. Adam Segal, a fellow for China studies at the Council on Foreign Relations, says stolen survey data is believed to have influenced bidding on Iraqi oil fields.

Attackers leave clues but are rarely caught. In 2011, the security firm McAfee described "operation Night Dragon," a series of computer intrusions at oil and

Invisible Threat
Recent cyberattacks on energy companies have gone unsolved

	Discovered	Suspected Source	Target
Stuxnet	2010	U.S./Israel	Iran's nuclear facility
Night Dragon	2010	China	Oil exploration data
Energetic Bear	2012	Russian Federation	Energy companies in 10 countries
Shamoon	2012	hacktivists	Saudi Aramco computers

SOURCES: MCAFEE, CROWDSTRIKE, MIT TECHNOLOGY REVIEW

gas companies that they traced to China. Researchers at CrowdStrike have been tracking an "adversary group" they call Energetic Bear, based in the Russian Federation, which strikes western energy firms by installing malware that collects passwords. The United States allegedly spied on the Brazilian state oil giant Petrobras.

Few companies will admit they've been the victims of espionage. One that did is American Superconductor. In 2011, the Massachusetts company sued its largest customer, the Chinese wind-turbine maker Sinovel, saying it had stolen its key technology, a way of making it easier for wind turbines to integrate with the electricity grid.

In August, a federal grand jury indicted Sinovel, alleging that it had offered money and an apartment in Beijing to induce an American Semiconductor employee to e-mail the source code for the technology to China. American Superconductor says it lost $800 million in revenues and its stock cratered, falling more than 75 percent.

The case points to how intellectual-property theft often relies not only on sophisticated computer attacks but also on insiders. But it justifies the care that 1366 takes, says CEO van Mierlo: "You only have to listen to the horrible stories of American Superconductor to know how damaging this stuff can be." —*Kevin Bullis*

Emerged Technologies

Before Snowden, There Was Huawei

The travails of a Chinese telecom company show how spying charges could hurt U.S. firms.

● How's this for a tough sales job? The American sales reps of Huawei offer top-notch telecom gear at a 35 percent discount. But anytime they get near to closing a sale, their customers get a visit from the FBI or the U.S. Department of Commerce.

The message from the feds isn't subtle: buy something else.

Huawei, based in Shenzhen, China, is the world's largest seller of telecom equipment, commanding 20 percent of the market. Yet it is barely a factor in North America. Here its market share in optical equipment is just 1.4 percent, and in switches and routers it's just 0.1 percent.

Just as Huawei has been shut out of the American market, leaks about the pervasiveness of spying by the NSA and other U.S. intelligence agencies might now hurt American companies abroad. Businesses are starting to talk of a "Snowden effect" of lost sales, dimmed prospects, and growing uncertainty, as they too come under a cloud of mistrust.

The U.S. worried that the Chinese government could be using commercial telecom gear to eavesdrop. No wonder. It appears American spies were doing the same.

Huawei (pronounced *wah-way*) was founded in 1987 by Ren Zhengfei, a former military officer who splits the CEO job with executives who rotate every six months. As Huawei expanded overseas, suspicions began to swirl around the company, particularly in the United States. Its effort to buy 3Com, a networking company, was blocked by a trade panel that assesses national security risks. In 2011, Cisco Systems, a competitor, developed talking-point slides that laid out reasons for "Fear of Huawei."

In 2012, partly at the Chinese company's request, the U.S. House Intelligence Committee investigated and released a report. It offered no real proof of spying, yet it still concluded that the United States must "view with suspicion" progress by Chinese companies in the North America telecommunications market.

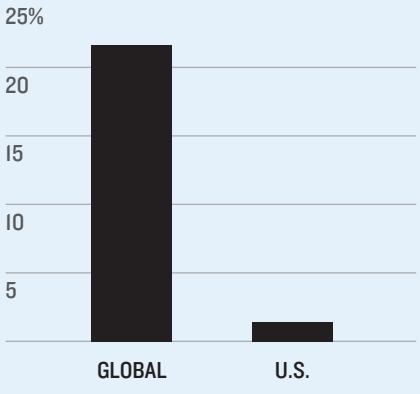
The concern was that somehow, with Huawei's knowledge or without it, the Chinese government could use equipment sold by the company to eavesdrop or even to gain an advantage in a cyberwar. Huawei loudly denied the charges; it cried "discrimination."

The irony now is that leaked National Security Agency documents suggest the U.S. was doing everything it suspected China of. The documents indicate that the U.S. may have compromised routers from Cisco, Juniper, and Huawei. It's also believed to have weakened encryption products so the ciphers used by commercial software could be broken.

The companies named in those leaks all deny knowing of the back doors. All say they are investigating. But the loss of trust is hurting U.S. companies. In December, Cisco said the allegations caused a significant drop in sales in China. "It's causing people to stop and then rethink decisions," Robert Lloyd, Cisco's president of development and sales, told investors. IBM's hardware sales in China plunged 40 percent in the financial quarter following the leaks.

Huawei can feel vindicated, but only to a degree. Its sales haven't picked up in the U.S., and now some alarmed European countries may also be reconsidering Chinese gear. "There's a universal lack of trust,

Closed Out
How mistrust of China shapes Huawei's market share



SOURCE: OVUM. REFERS TO OPTICAL TELECOMMUNICATIONS EQUIPMENT

and now we have a pretty obvious proof point of that," says William Plummer, Huawei's spokesman in Washington, D.C. As it turns out, everyone's gear is vulnerable. "We've been saying that for years," says Plummer.

In several white papers, Huawei has outlined what it thinks are ways to improve security by adopting common standards and, perhaps, checks by third parties. James Lewis, an analyst at the Center for Strategic and International Studies, describes the challenge ahead as "how to build trusted networks from untrustworthy components."

But the bigger fallout may be a rise in protectionism. "It's been mostly open competition since the beginning of the Internet, and the companies that did well are the ones that won the competitions," says Lewis. Now, with escalating security worries, countries may take the chance to stack the deck against foreign competitors or build up their own industries.

"The overall effect will be bad for the whole global economy," says Lewis.

—Antonio Regalado

Emerged Technologies

Spinoffs from Spyland

How America's eavesdropping agency commercializes technology.

● It takes more than a little tradecraft to spin off a startup from the National Security Agency.

Chris Lynch, an investor with Atlas Venture, knows this firsthand. Two years ago, he spent weeks trying to sign a deal with nervous NSA programmers who not only were sworn to secrecy but were barred from carrying cell phones at work. There were furtive Skype conversations and parking-lot phone calls that would end after strange clicks.

Eventually, $2 million in seed money was enough to lure five programmers from the NSA. These days they're working at Sqrrl, a company in Cambridge, Massachusetts, that's selling a commercial version of the database behind some of the spy agency's most controversial eavesdropping programs.

"These guys were government hacks working in a cave, and in a highly structured environment," says Lynch. "Kind of the opposite of an entrepreneur."

A blistering public debate surrounds the NSA's secret eavesdropping programs. But what's less well known is that the agency actively patents inventions and contributes to open-source projects, and that its employees occasionally—so far, very occasionally—emerge from secrecy to create spinoff companies.

Like other federal agencies, the NSA is compelled by law to try to commercialize its R&D. It employs patent attorneys and has a marketing department that is now trying to license inventions like tamper-proof bags, secure manhole covers, and a "dispersion system" to make sure shredded documents can't be pieced back together. One startup, Integrata, based in Maryland, exclusively licensed a patent on how to detect intruders on wireless networks.

Revelations about the extent of NSA spying have only increased demand for just the sorts of technology the agency excels at. And at least one NSA offshoot is developing products expressly to defeat the agency's snooping.

"We believe government surveillance has gone too far and individuals have lost their right to privacy," says Will Ackerly, who spent eight years building software for the NSA before founding Virtru, a Washington, D.C., company selling a secure file-sharing system that he says could defeat mass surveillance. Ackerly says he took another seven NSA engineers and contractors with him—about half the staff at his startup.

The NSA is one of 16 U.S. government organizations devoted to intelligence gathering (among them, only the CIA is larger). It has a budget of $10.5 billion a year, of which about $500 million is spent on more basic R&D in programming, optics, microelectronics, and quantum computing. The agency claims more than 170 patents, and it is even said to have invented the audiocassette.

16
Number of U.S. intelligence agencies

But the NSA has faced severe challenges trying to keep up with rapidly changing technology. Back in 1999, a new director, Michael Hayden, began efforts to shed aging spies after scathing reports that the agency was stuck in the "Telex age." It had failed to predict an Indian nuclear test and couldn't intercept North Korean signals because they were sent along fiber-optic cables, not over the air.

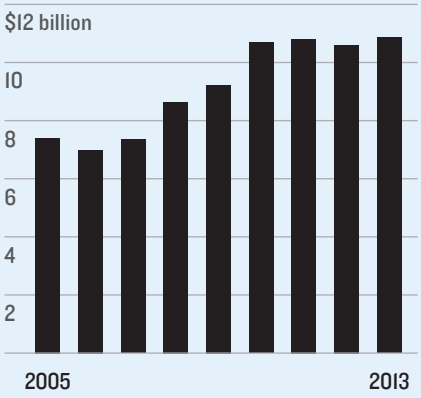
Most recently, the NSA's revamp included a sweeping effort to dismantle hundreds of single-purpose databases, or "stovepipes," and switch to flexible cloud computing, where data is spread across thousands of servers. In fact, in 2008, NSA brass ordered the agency's computer

Meet the NSA Spinouts
Startup companies based on technology from the National Security Agency

Integrata Security	Baltimore	$540,000 raised	Wireless monitoring systems
KeyW	Hanover, MD	Publicly traded	Geospatial intelligence
Six3 Systems	McLean, VA	Acquired	Surveillance solutions
Sqrrl	Cambridge, MA	$7.2 million raised	Enterprise databases
Fixmo	Toronto	$4I million raised	Mobile security

SOURCE: MIT TECHNOLOGY REVIEW

The NSA's Budget



and information sciences research organization to create a version of the system Google uses to store its index of the Web and the raw images of Google Earth.

That team was led by Adam Fuchs, now Sqrrl's chief technology officer. Its twist on big data was to add "cell-level security," a way of requiring a passcode for each data point in a spreadsheet. At the NSA, that's how software (like the infamous PRISM application) knows what can be shown only to people with top-secret clearance. Similar features could control access to data about U.S. citizens. "A lot of the technology we put [in] is to protect rights," says Fuchs.

Like other big-data projects, the NSA team's system, called Accumulo, was built on top of open-source code because "you don't want to have to replicate everything yourself," says Fuchs. But participating in the open-source community wasn't easy. When it came up with improvements, Fuchs's group had to find a third party to suggest a change without mentioning the NSA. That's why the NSA eventually decided to open-source Accumulo as well. Even though the move presented risks (coders' names would be known, and they could become targets of foreign surveillance), the NSA concluded that it would benefit if a wider community of software programmers worked on Accumulo.

In 2011, the NSA released 200,000 lines of code to the Apache Foundation. When Atlas Venture's Lynch read about that, he jumped—here was a technology already developed, proven to work on tens of terabytes of data, and with security features sorely needed by heavily regulated health-care and banking customers. When Fuchs's NSA team got cold feet about leaving, says Lynch, "I said 'Either you do it, or I'll find five kids from MIT to do it and they'll steal your thunder.'"

Eventually, Fuchs and several others left the NSA, and now their company is part of a land grab in big data, where several companies, like Splunk, Palantir, and Cloudera, have quickly become worth a billion dollars or more.

Over the summer, when debate broke out over NSA surveillance of Americans and others, Sqrrl tried to keep a low profile. But since then, it has found that its connection to the $10-billion-a-year spy agency is a boost, says Ely Kahn, Sqrrl's head of business development and a cofounder. "Large companies want enterprise-scale technology. They want the same technology the NSA has," he says.

The Sqrrl team is working 16-hour days. Fuchs says the pace is far more intense than it was at his old government job. And there are things he misses. His top-secret security clearance is on hold, and he's no longer part of the mission to protect the country. For the researchers and developers inside the NSA, "it's hard to empathize with whoever leaves," says Fuchs. "There's no system inside the NSA to leave and start companies. We wanted to maintain contacts, but it's been a challenge."

—Antonio Regalado

For some startups, the spying scandal has been good for business. Large companies want the same technology the NSA has.

Emerged Technologies

For Swiss Data Industry, NSA Leaks Are Good as Gold

Here's how the Swiss promise to keep your data safe.

● There is data security, and then there is Swiss data security.

The difference was explained to me by Stéphan Grouitch in a conference room deep within a mountain in the Swiss Alps, lit by a subterranean buzz of fluorescent lights. To get to here, under more than 3,000 feet of stone and earth, I showed my passport (something I didn't have to do to enter the country from Germany), had my finger scanned repeatedly, and passed under security cameras and motion detectors. A blast door, thicker than my forearm is long, is said to protect this old Cold War bunker against a 20-megaton bomb.

"The country has always stored valuables for people all around Europe—even before money," says Grouitch, CEO of Deltalis, the company that owns the bunker. When Deltalis first looked into acquiring the facility from the Swiss military, it considered storing gold bullion here. Instead, it now runs a farm of computer servers where data is safeguarded by strict privacy laws and a unique culture of discretion. To legally access someone's data here, you'll need an order from a Swiss judge.

A Swiss play in data security has been under way for around a decade, mostly in connection to banking. But the controversy around global surveillance by the U.S. National Security Agency is "a huge development," says Franz Grüter, CEO of Green, an Internet service provider whose state-of-the-art data center in the village of Lupfig is being filled out "years ahead of schedule."

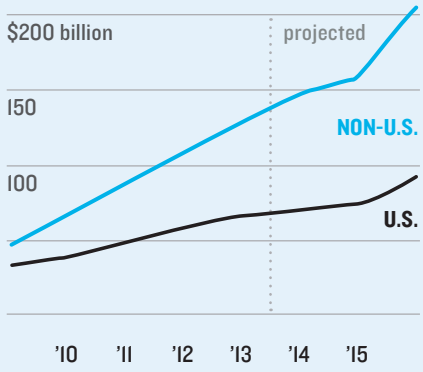
SOURCE: DIRECTOR OF NATIONAL INTELLIGENCE; INCLUDES RELATED DEFENSE PROGRAMS

To get a sense of the opportunity, one need only look at the projected losses the U.S.-based cloud services industry (including Google, Microsoft, and IBM) is facing because of anxiety and indignation over U.S. wiretapping. Estimates of lost market share through 2016 range from $35 billion to $180 billion (according to Forrester Research).

Switzerland isn't the only country hoping to cash in. Finland's F-Secure recently released a Dropbox competitor called Younited. And a consortium of German telecoms, ISPs, and e-mail providers has backed an "E-Mail Made in Germany" program that aims to keep communication data routed and stored in-country when possible. In February, German chancellor Angela Merkel attended talks in Paris on building an all-European communications network so that "one shouldn't have to send e-mails and other information across the Atlantic."

Spread the Risk

Cloud computing spending is shifting away from the U.S.



When ID Quantique took its products to market, it found early, and eager, customers in the banking industry and in government. Officials in Geneva have used its technology to help transmit federal election results since 2007, and in online voting for citizen initiatives since 2009.

So whom can you trust with your data? Grouitch thinks Switzerland's appeal should be obvious. "This country really is a vault in the center of Europe," he says.

—Russ Juskalian

European companies are now routinely questioning where data is physically stored.

European companies, according to Grüter, now routinely question where data is physically stored—and are declining U.S. offers. One result is that a cluster of privacy companies is forming in Switzerland. ID Quantique makes the Centauris CN8000, one of the world's first commercial encryption systems using quantum mechanics. And Blackphone, a secure handset launched by U.S. privacy pioneer Phil Zimmerman, will store subscribers' telephone numbers on Swiss servers.

Altogether, Switzerland has around 1,440,000 square feet of data-center space. While that is far less than is available in countries like the U.S. and Germany, it's a large amount when compared to Switzerland's population of 8 million.

Richard Straub, head of market development at ID Quantique, says Swiss innovations are backed by strong research at universities like EPFL in Lausanne, ETH-Zürich, and the University of Geneva. They also benefit from local demand.

SOURCE: THE INFORMATION TECHNOLOGY & INNOVATION FOUNDATION

Emerged Technologies

The Year of Encryption

Government spying gives a giant push to cryptography on the Web.

● Last summer, the world's largest Internet companies learned they'd been hacked by the U.S. government.

Their answer for 2014: encrypt everything.

Over the last eight months, Yahoo encrypted its e-mail service and Google extended encryption to every search term that users enter. Microsoft said that by the end of this year it plans to encrypt all the data traveling to and from its networks. "Encryption on the Web is expanding enormously," says Peter Eckersley, technology projects director at the Electronic Frontier Foundation (EFF), which grades companies on how well they do at protecting users' privacy.

The EFF believes that within a few years, every file crossing the Internet could be protected with encryption, which uses mathematics to scramble and unscramble messages.

Encryption does not guarantee complete privacy—ciphers can be broken or compromised. But its widespread use could seriously hinder both cybercriminals and bulk collection of data by governments. That's because even someone who is able to pilfer encrypted data can't easily read it.

Encryption was already a rising trend, even before the spy scandal. Major security breaches have shown that computer networks are not safe from intruders. Last year, hackers stole millions of credit card numbers from Target and Neiman Marcus after finding clever ways to gain access to their systems.

"Today's networks are like Swiss cheese. It's very easy to get in, move laterally, and exfiltrate data," says Dmitri Alperovitch, cofounder of the security firm CrowdStrike. "People are using tools from the 1990s to do it."

Encrypting data, like customers' credit card information, is an additional line of defense. But encrypting stored data (in contrast to data in transit) turns out to pose a difficult puzzle. Encrypting the data protects it but also makes it difficult to search or process—rendering it less useful.

Encryption also takes up computer time, the main reason Web companies like Yahoo didn't always use it before. But Internet firms realize they must now take extraordinary steps in response to extraordinary new threats.

—Robert Lemos

Emerged Technologies

For $3,500, a Spy-Resistant Smartphone

Prime ministers, business executives, and ordinary citizens clamor for phones that can't be snooped on.

● Ever since Edward Snowden came forward with a trove of secret documents about the National Security Agency, business has been booming for Les Goldsmith, CEO of ESD America.

Goldsmith's company sells a $3,500 "cryptophone" that scrambles calls so they can't be listened in on. Until recently, the high-priced smartphone was something of a James Bond–style novelty item. But news of extensive U.S. eavesdropping on people including heads of state has sent demand from wary companies and governments soaring. "We're producing 400 a week and can't really keep up," says Goldsmith.

The Las Vegas–based company prepares and packages the device, called the GSMK CryptoPhone, by first wiping the software from an ordinary $350 Samsung Galaxy S3 handset. It then adds a version of Google's Android operating system, licensed from the German company GSMK, that has been tweaked to add call encryption and fix security flaws.

Sales have tripled since Snowden's revelations began last June, and close to 100,000 of the handsets are in use worldwide, according to Goldsmith. Secure calls work only between two cryptophones. To set up a secure connection, each handset creates a cryptographic key based on a sample of random background noise. Everything takes place on the handsets, so no unprotected data leaves the device.

Secure phones aren't new. In the 1970s, the NSA developed a "secure telephone unit" that featured an ordinary-looking push-button landline phone connected to a crate-size scrambler. What has changed is that consumer smartphones have created an explosion of new opportunities for snooping. Handsets can be infected by malware that listens to calls, copies data, or transmits a device's location. Some spies even employ fake base stations, known as interceptors, that harvest calls and text messages.

That's reason enough for politicians, dissidents, and top executives to worry. Last year, the prime minister of Turkey ordered cryptophones for all his ministers after discovering bugs in his office and car. At ESD, Goldsmith says, most of his customers are U.S. multinationals worried about economic espionage by China, whose military conducts large-scale efforts to pilfer data. "We get a lot of people who have had information from one-to-one discussions over the telephone somehow get out," he says.

Examples aren't hard to come by. In February, a politically embarrassing conversation between a U.S. State Department staffer and the American ambassador to Ukraine was leaked onto YouTube. "All Department of State government-owned BlackBerry devices have data encryption. However, they don't have voice encryption," said State Department spokeswoman Jen Psaki.

The CryptoPhone's $3,500 price tag includes three years of service, not including calling charges. That puts the device beyond the reach of most individuals and small businesses. A competing device, the Hoox m2 smartphone that French IT contractor Bull began selling in January, sells for 2,000 euros ($2,740) and is also aimed at corporate users.

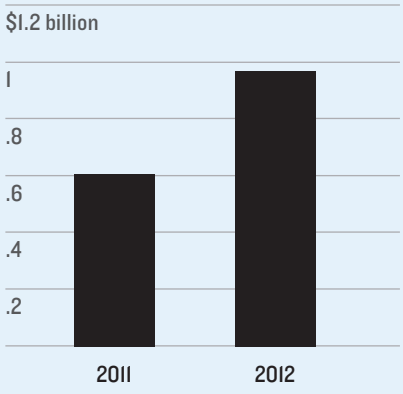
For the most part, consumers haven't joined the security rush. According to Gartner, a firm that tracks technology trends, few have even purchased antivirus software for their phones. Sales of mobile security software are about $1 billion a year, a fraction what's spent on desktops, even though mobile devices now outnumber PCs.

Yet secure communication products could eventually have mass appeal as consumers tire of being tracked online. Some of the most successful apps of the past year have featured self-destructing messages or anonymous bulletin boards.

Companies on a budget could turn to the $629 Blackphone handset, which launched in February and also offers encrypted calling. The device is the product of a joint venture between Spanish smartphone startup Geeksphone and Silent Circle, a company that markets apps for encrypted calling and e-mail on Apple and Android devices.

The Blackphone lacks some premium security features, like the ability to foil fake-base-station attacks, and it isn't marketed as being "NSA-proof" either. But it still offers significantly better security and privacy than a conventional handset, says Javier Agüera, cofounder and chief technology officer of Geeksphone. "Blackphone is for the people, not just a small elite," he says. —*Tom Simonite*

Run to Safety
Global spending on security software for mobiles is growing



Cryptophones Offer Secure Calls

Blackphone	$629	Disables Wi-Fi tracking
GSMK CryptoPhone	$3,500	Secure Samsung Galaxy S3
HOOX m2	$2,740	Biometric identification
In Confidence	$1,659	Unlimited Internet calls
Secusmart	$3,436	Encrypted BlackBerry Z10

SOURCE: MIT TECHNOLOGY REVIEW | SOURCE: INFONETICS

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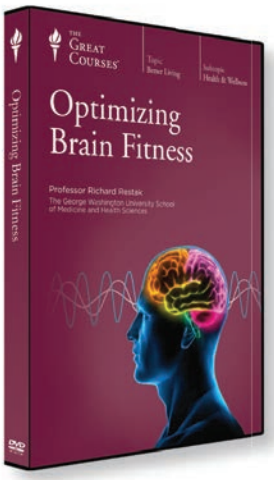

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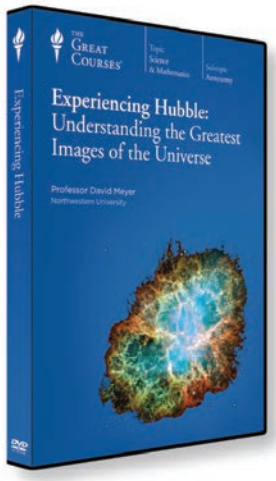

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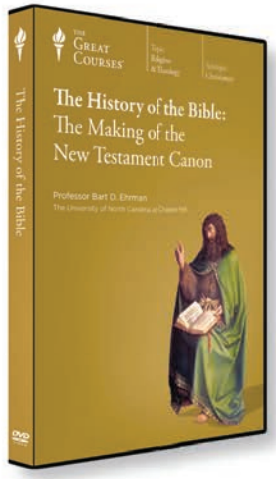

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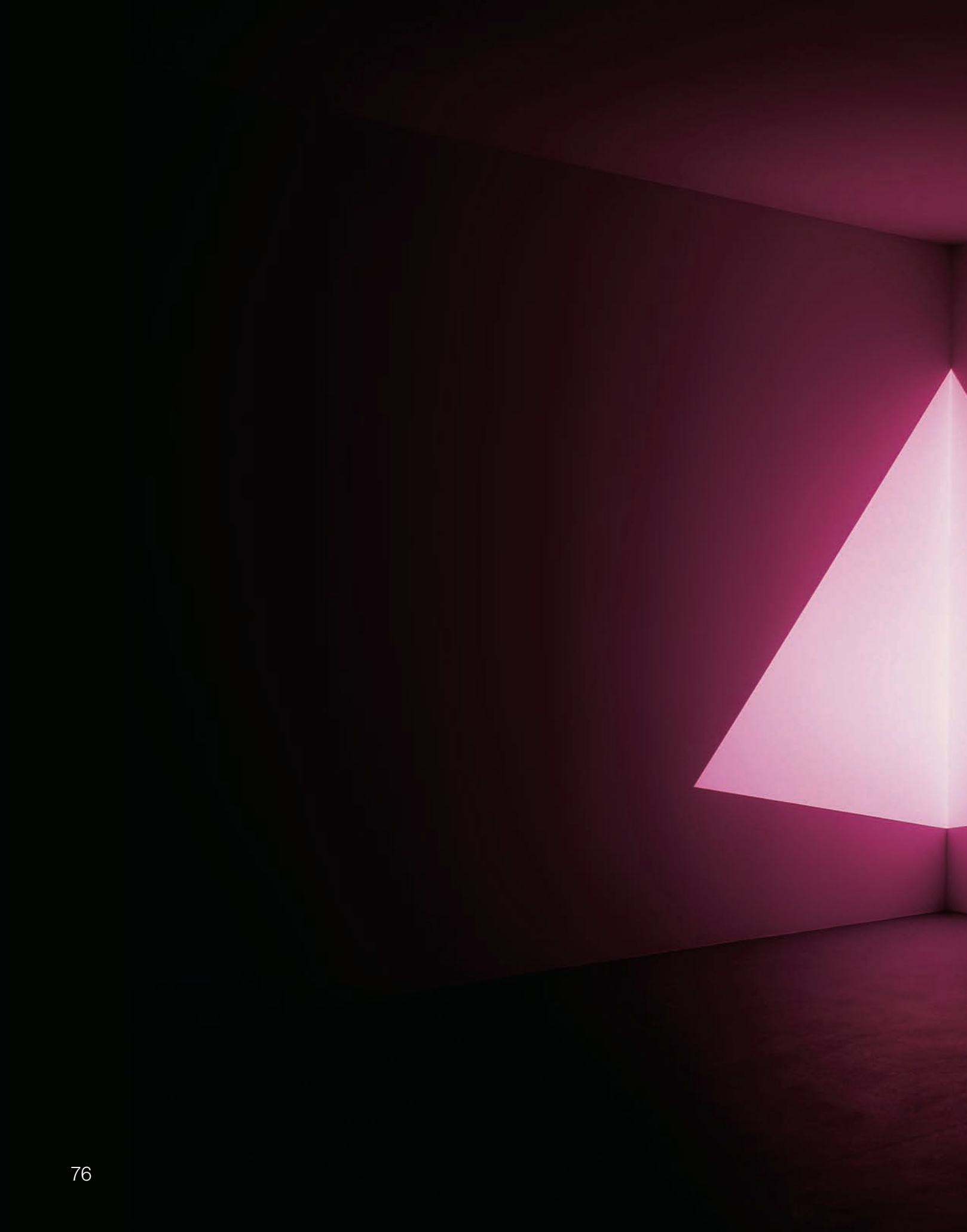

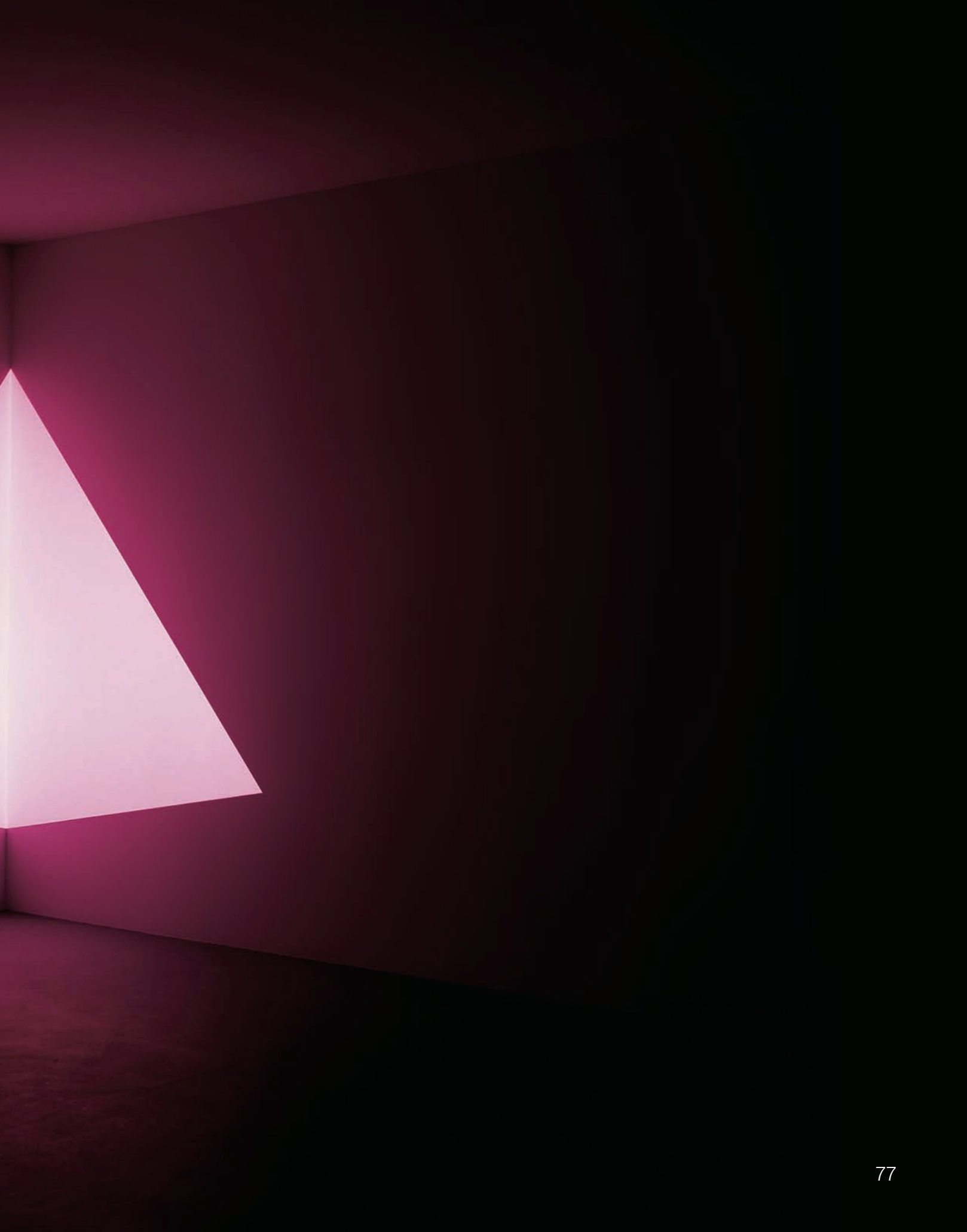

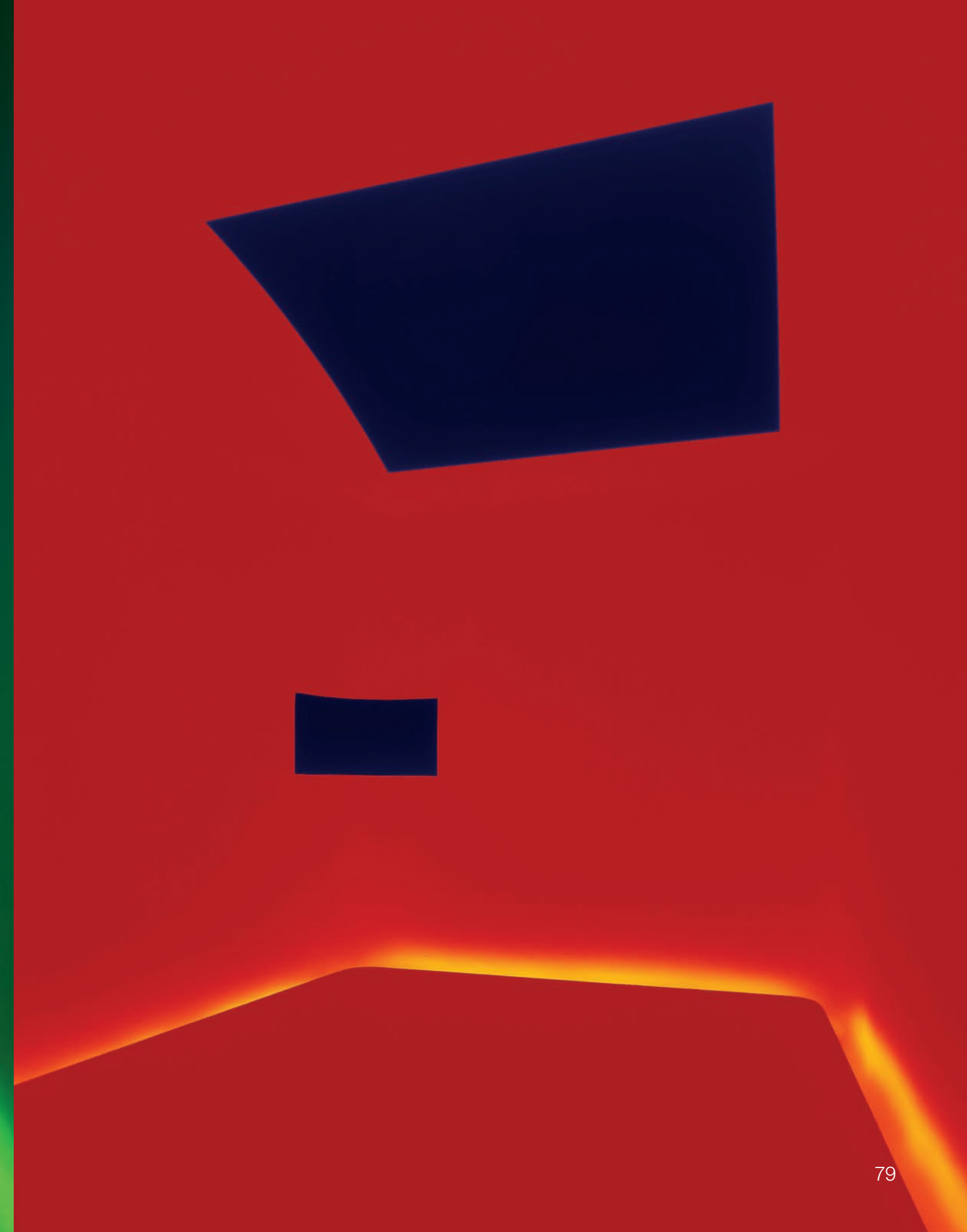

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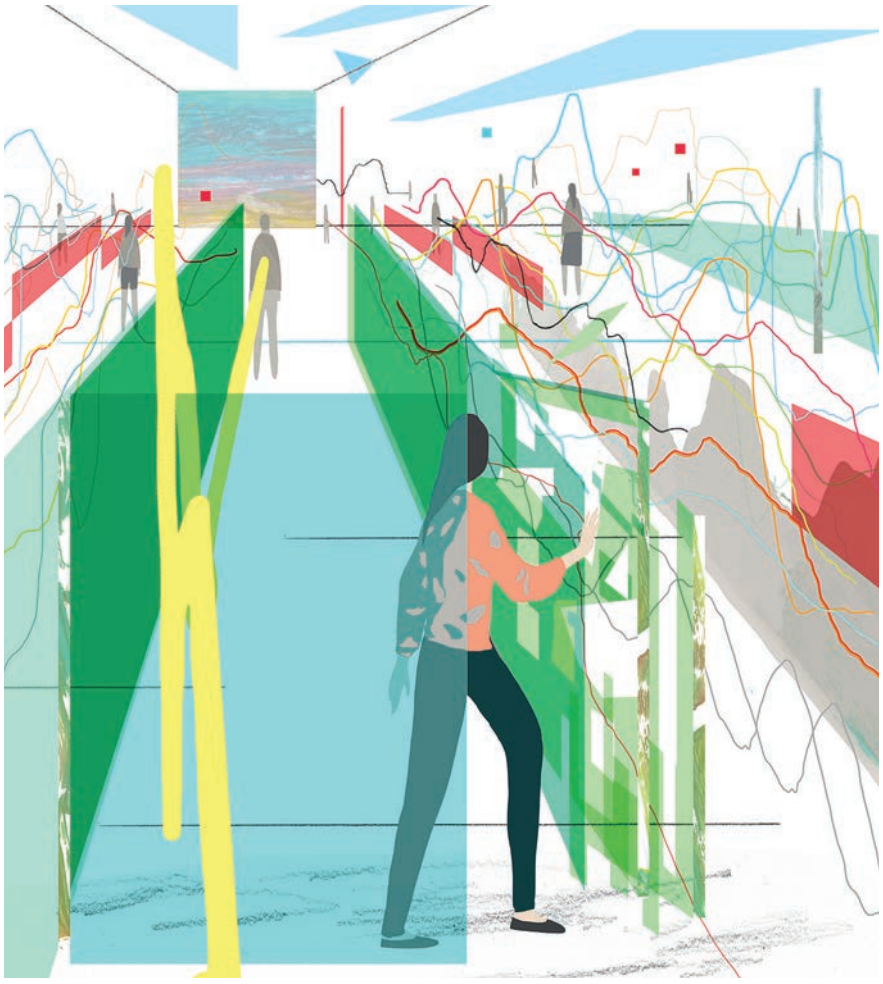


The Limits of Social Engineering

Tapping into big data, researchers and planners are building mathematical models of personal and civic behavior. But the models may hide rather than reveal the deepest sources of social ills.

By Nicholas Carr

IN 1969, *PLAYBOY* PUBLISHED A LONG, freewheeling interview with Marshall McLuhan in which the media theorist and sixties icon sketched a portrait of the future that was at once seductive and repellent. Noting the ability of digital computers to analyze data and communicate messages, he predicted that the machines eventually would be deployed to fine-tune society's workings. "The computer can be used to direct a network of global thermostats to pattern life in ways that will optimize human awareness," he said. "Already, it's technologically feasible to employ the computer to program societies in beneficial ways." He acknowledged that such centralized control raised the specter of "brainwashing, or far worse," but he stressed that "the programming of societies could actually be conducted quite constructively and humanistically."

The interview appeared when computers were used mainly for arcane scientific and industrial number-crunching. To most readers at the time, McLuhan's words must have sounded far-fetched, if not nutty. Now they seem prophetic. With smartphones ubiquitous, Facebook inescapable, and wearable computers like Google Glass emerging, society is gaining a digital sensing system. People's location and behavior are being tracked as they go through their days, and the resulting information is being transmitted instantaneously to vast server farms. Once we write the algorithms needed to parse all that "big data," many sociologists and statisticians believe, we'll be rewarded with a much deeper understanding of what makes society tick.

One of big data's keenest advocates is Alex "Sandy" Pentland, a data scientist who, as the director of MIT's Human Dynamics Laboratory, has long used computers to study the behavior of businesses and other organizations. In his brief but ambitious new book, *Social Physics,* Pentland argues that our greatly expanded ability to gather behavioral data will allow scientists to develop "a causal theory of social structure" and ultimately establish "a mathematical explanation for why society reacts as it does" in all manner of circumstances. As the book's title makes clear, Pentland thinks that the social world, no less than the material world, operates according to rules. There are "statistical regularities within human movement and communication," he writes, and once we fully understand those regularities, we'll discover "the basic mechanisms of social interactions."

What's prevented us from deciphering society's mathematical underpinnings up to now, Pentland believes, is a lack of empirical rigor in the social sciences. Unlike physicists, who can measure the movements of objects with great precision, sociologists have had to make do with fuzzy observations. They've had to

Social Physics: How Good Ideas Spread—The Lessons from a New Science
By Alex Pentland
Penguin Press, 2014

JON HAN

work with rough and incomplete data sets drawn from small samples of the population, and they've had to rely on people's notoriously flawed recollections of what they did, when they did it, and whom they did it with. Computer networks promise to remedy those shortcomings. Tapping into the streams of data that flow through gadgets, search engines, social media, and credit card payment systems, scientists will be able to collect precise, real-time information on the behavior of millions, if not billions, of individuals. And because computers neither forget nor fib, the information will be reliable.

To illustrate what lies in store, Pentland describes a series of experiments that he and his associates have been conducting in the private sector. They go into a business and give each employee an electronic ID card, called a "sociometric badge," that hangs from the neck and communicates with the badges worn by colleagues. Incorporating microphones, location sensors, and accelerometers, the badges monitor where people go and whom they talk with, taking note of their tone of voice and even their body language. The devices are able to measure not only the chains of communication and influence within an organization but also "personal energy levels" and traits such as "extraversion and empathy." In one such study of a bank's call center, the researchers discovered that productivity could be increased simply by tweaking the coffee-break schedule.

Pentland dubs this data-processing technique "reality mining," and he suggests that similar kinds of information can be collected on a much broader scale by smartphones outfitted with specialized sensors and apps. Fed into statistical modeling programs, the data could reveal "how things such as ideas, decisions, mood, or the seasonal flu are spread in the community."

The mathematical modeling of society is made possible, according to Pent-

land, by the innate tractability of human beings. We may think of ourselves as rational actors, in conscious control of our choices, but most of what we do is reflexive. Our behavior is determined by our subliminal reactions to the influence of other people, particularly those in the various peer groups we belong to. "The power of social physics," he writes, "comes from the fact that almost all of our day-to-day actions are habitual, based mostly on what we have learned from observing the behavior of others." Once you map and measure all of a person's social influences, you can develop a statistical model that predicts that person's behavior, just as you can model the path a billiard ball will take after it strikes other balls.

Pentland's idea of a "data-driven society" is problematic. It will encourage us to optimize the status quo rather than challenge it.

Deciphering people's behavior is only the first step. What really excites Pentland is the prospect of using digital media and related tools to change people's behavior, to motivate groups and individuals to act in more productive and responsible ways. If people react predictably to social influences, then governments and businesses can use computers to develop and deliver carefully tailored incentives, such as messages of praise or small cash payments, to "tune" the flows of influence in a group and thereby modify the habits of its members. Beyond improving the efficiency of transit and health-care systems, Pentland suggests, group-based incentive programs can make communities more harmonious and creative. "Our main insight," he reports, "is that by targeting [an] individual's peers, peer pressure can amplify the desired effect of a reward on the target individual." Computers become, as McLuhan envisioned, civic thermostats. They not only register society's state but bring it into line with some prescribed ideal. Both the tracking and the maintenance of the social order are automated.

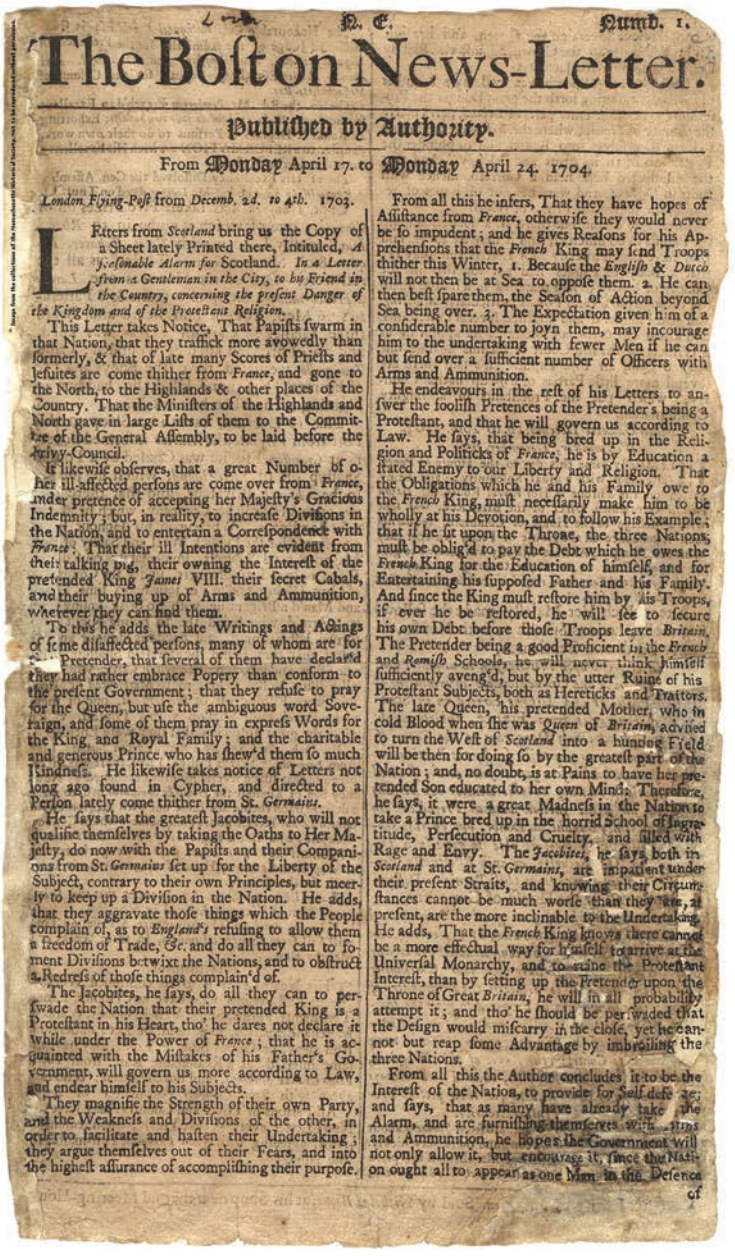
Ultimately, Pentland argues, looking at people's interactions through a mathematical lens will free us of time-worn notions about class and class struggle. Political and economic classes, he contends, are "oversimplified stereotypes of a fluid and overlapping matrix of peer groups." Peer groups, unlike classes, are defined by "shared norms" rather than just "standard features such as income" or "their relationship to the means of production." Armed with exhaustive information about individuals' habits and associations, civic planners will be able to trace the full flow of influences that shape personal behavior. Abandoning general categories like "rich" and "poor" or "haves" and "have-nots," we'll be able to understand people as individuals—even if those individuals are no more than the sums of all the peer pressures and other social influences that affect them.

Replacing politics with programming might sound appealing, particularly given Washington's paralysis. But there are good reasons to be nervous about this sort of social engineering. Most obvious are the privacy concerns raised by collecting ever more intimate personal information. Pentland anticipates such criticisms by arguing for a "New Deal on Data" that gives people direct control over the information collected about them. It's hard, though, to imagine Internet companies agreeing to give up ownership of the behavioral information that is crucial to their competitive advantage.

Even if we assume that the privacy issues can be resolved, the idea of what Pentland calls a "data-driven society" remains problematic. Social physics is a variation on the theory of behavioralism that found favor in McLuhan's day, and it suffers from the same limitations that doomed its predecessor. Defining social relations as a pattern of stimulus and response makes the math easier, but it ignores the deep, structural sources of social ills. Pentland may be right that our behavior is determined largely by social norms and the influences of our peers, but what he fails to see is that those norms and influences are themselves shaped by history, politics, and economics, not to mention power and prejudice. People don't have complete freedom in choosing their peer groups. Their choices are constrained by where they live, where they come from, how much money they have, and what they look like. A statistical model of society that ignores issues of class, that takes patterns of influence as givens rather than as historical contingencies, will tend to perpetuate existing social structures and dynamics. It will encourage us to optimize the status quo rather than challenge it.

Politics is messy because society is messy, not the other way around. Pentland does a commendable job in describing how better data can enhance social planning. But like other would-be social engineers, he overreaches. Letting his enthusiasm get the better of him, he begins to take the metaphor of "social physics" literally, even as he acknowledges that mathematical models will always be reductive. "Because it does not try to capture internal cognitive processes," he writes at one point, "social physics is inherently probabilistic, with an irreducible kernel of uncertainty caused by avoiding the generative nature of conscious human thought." What big data can't account for is what's most unpredictable, and most interesting, about us.

Nicholas Carr writes on technology and culture. His new book, The Glass Cage: Automation and Us, *will be published in September.*



N. E. Numb. 1.

The Boston News-Letter.

Published by Authority.

From Monday April 17. to Monday April 24. 1704.

London Flying-Post from *Decemb.* 22. *to* 25*th.* 1703.

LEtters from *Scotland* bring us the Copy of a Sheet lately Printed there, Intituled, *A seasonable Alarm for* Scotland. *In a Letter from a Gentleman in the City, to his Friend in the Country, concerning the present Danger of the Kingdom and of the Protestant Religion.*

This Letter takes Notice, That Papists swarm in that Nation, that they traffick more avowedly than formerly, & that of late many Scores of Priests and Jesuites are come thither from *France*, and gone to the North, to the Highlands & other places of the Country. That the Ministers of the Highlands and North gave in large Lists of them to the Committee of the General Assembly, to be laid before the Privy-Council.

It likewise observes, that a great Number of other ill-affected persons are come over from *France*, under pretence of accepting her Majesty's Gracious Indemnity; but, in reality, to increase Divisions in the Nation, and to entertain a Correspondence with *France*: That their ill Intentions are evident from their talking big, their owning the Interest of the pretended King *James* VIII. their secret Cabals, and their buying up of Arms and Ammunition, wherever they can find them.

To this he adds the late Writings and Actings of some disaffected persons, many of whom are for the Pretender, that several of them have declar'd they had rather embrace Popery than conform to the present Government; that they refuse to pray for the Queen, but use the ambiguous word Sovereign, and some of them pray in express Words for the King and Royal Family; and the charitable and generous Prince who has shew'd them so much Kindness. He likewise takes notice of Letters not long ago found in Cypher, and directed to a Person lately come thither from St. *Germains*.

He says that the greatest Jacobites, who will not qualifie themselves by taking the Oaths to Her Majesty, do now with the Papists and their Companions from St. *Germains* set up for the Liberty of the Subject, contrary to their own Principles, but meerly to keep up a Division in the Nation. He adds, that they aggravate those things which the People complain of, as to *England's* refusing to allow them a freedom of Trade, &c. and do all they can to foment Divisions betwixt the Nations, and to obstruct a Redress of those things complain'd of.

The Jacobites, he says, do all they can to perswade the Nation that their pretended King is a Protestant in his Heart, tho' he dares not declare it while under the Power of *France*; that he is acquainted with the Mistakes of his Father's Government, will govern us more according to Law, and endear himself to his Subjects.

They magnifie the Strength of their own Party, and the Weakness and Divisions of the other, in order to facilitate and hasten their Undertaking; they argue themselves out of their Fears, and into the highest assurance of accomplishing their purpose.

From all this he infers, That they have hopes of Assistance from *France*, otherwise they would never be so impudent; and he gives Reasons for his Apprehensions that the *French* King may send Troops thither this Winter, 1. Because the *English* & *Dutch* will not then be at Sea to oppose them. 2. He can then best spare them, the Season of Action beyond Sea being over. 3. The Expectation given him of a considerable number to joyn them, may incourage him to the undertaking with fewer Men if he can but send over a sufficient number of Officers with Arms and Ammunition.

He endeavours in the rest of his Letters to answer the foolish Pretences of the Pretender's being a Protestant, and that he will govern us according to Law. He says, that being bred up in the Religion and Politicks of *France*, he is by Education a stated Enemy to our Liberty and Religion. That the Obligations which he and his Family owe to the *French* King, must necessarily make him to be wholly at his Devotion, and to follow his Example; that if he sit upon the Throne, the three Nations must be oblig'd to pay the Debt which he owes the *French* King for the Education of himself, and for Entertaining his supposed Father and his Family. And since the King must restore him by his Troops, if ever he be restored, he will see to secure his own Debt before those Troops leave *Britain*. The Pretender being a good Proficient in the *French* and *Romish* Schools, he will never think himself sufficiently aveng'd, but by the utter Ruine of his Protestant Subjects, both as Hereticks and Traitors. The late Queen, his pretended Mother, who in cold Blood when she was *Queen* of *Britain*, advised to turn the West of *Scotland* into a hunting Field will be then for doing so by the greatest part of the Nation; and, no doubt, is at Pains to have her pretended Son educated to her own Mind. Therefore, he says, it were a great Madness in the Nation to take a Prince bred up in the horrid School of Ingratitude, Persecution and Cruelty, and filled with Rage and Envy. The *Jacobites*, he says, both in *Scotland* and at St. *Germains*, are impatient under their present Straits, and knowing their Circumstances cannot be much worse than they are, at present, are the more inclinable to the Undertaking. He adds, That the *French* King knows there cannot be a more effectual way for him self to arrive at the Universal Monarchy, and to ruine the Protestant Interest, than by setting up the Pretender upon the Throne of Great *Britain*, he will in all probability attempt it; and tho' he should be perswaded that the Design would miscarry in the close, yet he cannot but reap some Advantage by imbroiling the three Nations.

From all this the Author concludes it to be the Interest of the Nation, to provide for Self defence; and says, that as many have already take the Alarm, and are furnishing themselves with Arms and Ammunition, he hopes the Government will not only allow it, but encourage it, since the Nation ought all to appear as one Man in the Defence of

The Boston News-Letter *was a business built on curating the news.*

COURTESY OF WIKIMEDIA COMMONS

A Better Breed of News App

Mobile news curation uses human editors and good design to improve the experience of reading the news on smartphones.

By Jason Pontin

In 1704, John Campbell, boston's postmaster, turned his handwritten newsletter into a printed half-sheet, called it the *Boston News-Letter*, and founded the first continuously published newspaper in the Colonies. He soon found a circulation of around 250 eager subscribers. "Royal proclamations and international news appeared first, followed by news from other colonies, and finally local news," writes the journalist Tom Standage in *Writing on the Wall: Social Media—the First 2,000 Years*. "Campbell gathered information by talking to sailors, travelers, local officials, and visitors to his post office, and via handwritten newsletters from other postmasters. But most of the stories in the *Boston News-Letter* were simply copied from the London papers." Campbell had been writing a kind of blog, which he made into a business that curated the news.

Facebook Paper for the iPhone
Free in Apple's App Store

Inside, for the iPhone and BlackBerry
Free in their respective app stores; Inside.com, a mobile website

For much of history, news was disseminated like this. The industrial age of news, when consumers were loyal to a newspaper that did most of its own reporting, was relatively short-lived. Since the creation of the World Wide Web, people have again become used to reading news aggregated from a variety of sources, and in recent years, since smartphones have become common, the most popular medium for browsing the news has been the app or mobile website. Publishers don't like apps much, but they work well for curators, and during the last few months the field of mobile news curation has enjoyed a blossoming of investment and creativity.

To date, the taxonomy of news apps has been three-part: there are apps associated with individual publishers, such

as the *Economist*, the *Financial Times*, and the *Huffington Post*; apps that use machine-based methods to curate and condense news from a variety of sources, like Pulse, Zite, and Summly (the last, created by a teenage entrepreneur named Nick D'Aloisio, employs a little artificial intelligence to summarize articles; it was purchased by Yahoo for about $30 million); and apps that users themselves set up, such as Feedly and NetNewsWire, among many others. Two new apps, Inside and Paper, take another approach: they also curate from a variety of sources, but the news they show readers has been selected from trusted publications by humans. Both apps have been designed in conformity to the Jobsian aesthetic of radical simplicity. Yet this common strategy produces very different results.

Atomic units

Inside (there is also a website, Inside.com), the child of the Web entrepreneur Jason Calacanis, tries to show its users *all* the news. "I would like to be everyone's starting point for news," says Calacanis (who earlier in his career published the *Silicon Alley Reporter* and cofounded the blog network Weblogs and the search engine Mahalo). "We are already covering about one-third of the medium and fat tail of content every day. [He means that Inside will never cover the "long tail" of niche-interest news stories, which individually appeal to very few readers.] If we triple our coverage and hit 2,500 to 3,500 updates a day, we will cover every major and minor story in every major and medium publication in the USA."

The interface of Inside recalls multiple, stacked decks of cards: a river of news displays story after story, and underneath each swipeable story are more stories within associated topic areas. What Calacanis calls "the atomic unit of news" is the update: a photo, a headline, and about 250 characters of text, containing about five or six facts. The app's functionality is limited to a prominent link back to the original source and the ability to like, dislike, comment upon, or share a story. Liking a story means the user will be shown similar stories in "My Feed."

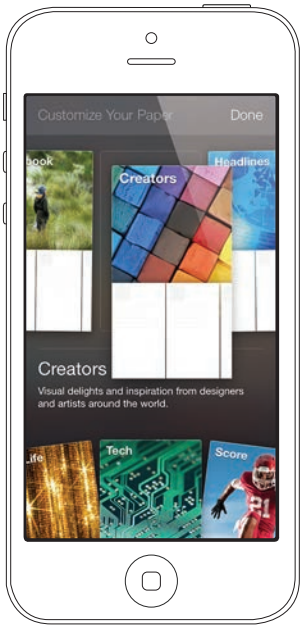
The news updates, which draw from more than 100 publications, are written by a team of freelancers, who report to an actual editor. Calacanis claims his purpose is "to destroy all the worthless reblogging and get folks focused on the original reporting." He says, "When we looked at a site like *Business Insider,* we saw that one of their five stories is awesome original reporting and the other four are link-baiting, social-rehashing jobs. When we see awesome pieces, we find the original source and link to it." This emphasis on original reporting is not unironic, given that Inside produces no new journalism itself. But as Calacanis has admitted, investors (his own include names like Sequoia Capital, Elon Musk, and Fred Wilson) "generally don't like content."

Paper was developed by Facebook's Creative Labs, an indulged group within the social-networking giant whom Mark Zuckerberg liberated to develop weird or interesting apps and projects. Zuckerberg hopes that the best ideas at Creative Labs will be applicable to Facebook's mobile or desktop products and allow a risk-averse public company to remain true to its unofficial motto, "Move fast and break things." But Michael Reckhow, Paper's product manager, denies that the app is an experiment. He also says it's not solely a news app: "We didn't intend to fix news apps. We created a better way to share."

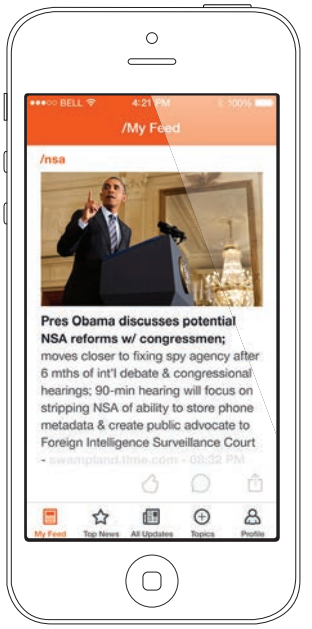
Reckhow may dislike the word "experiment," but it's hard not to see Paper as an attempt to imagine what Facebook's iPhone app might be if it weren't so *Facebooky*—if it had been developed by people with good taste in graphic design, solicitude for the user's experience, interest in real news, and an airy indifference to advertising revenue. Paper eliminates Facebook's long news feed. Instead, the user is confronted by a series of tiles representing topics—little magazines—among which one may browse by swiping leftward: one's friends' posts on Facebook, "Headlines," "Tech," "Creators," "Ideas," "Planet," "Flavor," "Enterprise," and so on. Underneath each topic is a horizontal scroll of stories, selected by curators and algorithms from quality publications as well as individuals on Facebook, whose final content and order is the choice of the curators. (Reckhow explains, "There's power in the combination of curators and algorithms.") Tapping on a story expands an update, which is not unlike Inside's atomic unit, so that it fills the entire iPhone screen. Tapping again makes the story itself unfold like a piece of paper.

Paper is what Facebook's app might have been like if it had been developed by people with good taste in graphic design and an indifference to advertising revenue.

Paper's chief designer, Mike Matas, who previously helped design the Nest thermostat and cofounded the digital publishing company Push Pop Press, spent a lot of time thinking about how stories would look. Publishers' fonts are reproduced respectfully. The brands of publishers are emphasized (for instance, updates from *National Geographic* retain the traditional yellow border of that magazine's cover) at the expense of Facebook's own branding. "We wanted to honor the



Paper eliminates Facebook's long news feed. Instead, the user is confronted by a series of tiles among which one may browse by swiping.



Inside's functionality is limited to a prominent link back to the original source and the ability to like, dislike, comment upon, or share a story.

COURTESY OF FACEBOOK; COURTESY OF INSIDE

content in the most authentic way possible," says Matas. Another way he honored the content was by stripping away all the navigation bars and icons—the "chrome," in the jargon of UX designers—that we've come to expect in mobile applications, and which persist in Inside. One explores the stories using natural gestures: swiping downward closes a story; swiping down again returns you to the horizontal scroll of a magazine. As with Inside, functionality is limited: the reader can like, comment, or share. Unlike Inside, however, Paper allows users to create their own stories and post them to Facebook.

Both apps are works in progress, representative of Silicon Valley's reigning dogma of "agile development," in which companies are enjoined to "deploy or die." Here, companies launch "minimal viable products," and features are added quickly in response to data-driven testing. As a result, both apps feel unfinished. So far, one can't search for stories inside Inside. Right now, Paper doesn't permit customization of the news feeds. But both apps are beautiful, Paper especially so. Inside is a much better news app, providing a fuller sense of the news; but Paper provides a more enjoyable, better-edited curation of *some* of the day's news and improves Facebook's essential functionality of sharing updates among friends.

Of course, one big reason both apps are so austerely beautiful is that they have no ads. Reckhow says, "We think of ourselves as a startup. We're focused on whether people use the app every day. We'll think about advertising later." Calacanis expands on the idea: "The model in startup land is simply to get 1 to 10 percent compounded growth each week. Money is free for startups that grow at 1 percent or better. At some point, when we hit scale, which today is defined as 20 to 100 million monthly users, I see two ways to make money: subscriptions or native advertising."

Higher gossip

I liked the apps. I found myself using Paper in preference to Facebook's real iPhone app in order to follow my friends, and I consult Inside once or twice a day. They're quite popular with other people, too. Since its release in January, Inside has fluctuated between sixth and 859th in the U.S. News category of iOS store apps (based on the number of times it's been downloaded), according to App Annie, a market research firm. Paper debuted in the iOS store last February at number 1 in the U.S. Social Networking category and second overall.

Both apps make browsing the news so frictionless, compulsive, and pleasurable that I began to wonder why we are attracted to the news in the first place. What is the utility of general news—I mean, news not read for competitive advantage in trade or in one's career? For an economist, the answer is straightforward. Says Erik Brynjolfsson, the director of the Center for Digital Business at MIT's Sloan School of Management, "General news is simply an end in itself, like music, food, or play. By definition, anything that gives us 'happiness' has utility." Economists can even measure utility by comparing what the late Paul Samuelson called the "revealed preferences" of consumers: whether they would prefer to listen to a Velvet Underground song or read a story by David Rotman.

Like other straightforward answers from economists, this is true, yet unhelpful. The pop philosopher Alain de Botton suggests that the purpose of the news is to distract us: "We read the weird tales in newspapers to crowd out the even weirder stuff inside us." But a sociological answer is probably the most honest. The news is a kind of higher gossip. It satisfies our curiosity and interest and disseminates ideas and opinions. Those are not small things. Because mobile news-curation apps like Inside and Paper make reading the news easier than ever before, they are little machines for good.

Jason Pontin is the editor in chief of MIT Technology Review.

13 Years Ago

The Myth of a Free Internet

A 2001 essay warned advocates of free expression not to delude themselves into thinking the Internet can never be controlled.

BY CHARLES C. MANN
ILLUSTRATIONS BY BRIAN CRONIN

TAMING THE WEB

In December, Vincent Falco, a 28-year-old game programmer in West Palm Beach, FL, released version 1.0 of a pet project he called BearShare. BearShare is decentralized file-sharing software—that is, it allows thousands of Internet users to search each other's hard drives for files and exchange them without any supervision or monitoring. Released free of charge, downloaded millions of times, BearShare is a raspberry in the face of the music, film and publishing industries: six months after the release of version 1.0, tens of thousands of songs, movies, videos and texts were coursing through the network every day. Because the software links together a constantly changing, ad hoc collection of users, Falco says, "there's no central point for the industries to attack." BearShare, in other words, is unstoppable.

Which, to Falco's way of thinking, is entirely unsurprising—almost a matter of course. BearShare is just one more example, in his view, of the way that digital technology inevitably sweeps aside any attempt to regulate information. "You can't stop people from putting stuff on the Net," Falco says. "And once something is on the Net you can't stop it from spreading everywhere."

The Internet is unstoppable! The flow of data can never be blocked! These libertarian claims, exemplified by software like BearShare, have become dogma to a surprisingly large number of Internet users. Governments and corporations may try to rein in digital technology, these people say, but it simply will never happen because...*information wants to be free.* Because, in a phrase attributed to Internet activist John Gilmore, *the Net treats censorship as damage and routes around it.* Laws, police, governments and corporations—all are helpless before the continually changing, endlessly branching, infinitely long river of data that is the Net.

To the generations nurtured on *1984*, Cointelpro and *The Matrix*, the image of a global free-thought zone where people will always be able to say and do what they like has obvious emotional appeal. Little wonder that the

"Information wants to be free." "The Internet can't be controlled." We've heard it so often that we sometimes take for granted that it's true. But THE INTERNET CAN BE CONTROLLED, and those who argue otherwise are hastening the day when it will be controlled too much, by the wrong people, and for the wrong reasons.

44

"TO THE GENERATIONS nurtured on *1984*, Cointelpro, and *The Matrix,* the image of a global free-thought zone where people will always be able to say and do what they like has obvious emotional appeal. Little wonder that the notion of the Net's inherent uncontrollability has migrated to the mainstream media from the cyberpunk novels and technoanarchist screeds where it was first articulated in the late 1980s. A leitmotif in the discussion of the Napster case, for example, was the claim that it was futile for the recording industry to sue the file-swapping company because an even more troublesome file-swapping system would inevitably emerge.

Nonetheless, the claim that the Internet is ungovernable by its nature is more of a hope than a fact.

Insisting that digital technology is ineluctably beyond the reach of authority [is] inadvertently making it far more likely that the rules of operation of the Internet will be established not through the messy but open processes of democracy but by private negotiations among large corporations.

We are in the beginning stages of the transfer of most of society's functions—working, socializing, shopping, acting politically—from what Internet denizens jokingly call "meatspace" into the virtual domain. In the real world, these functions are wrapped in a thicket of regulations and cultural norms that are, for the most part, accepted. Some free-speech absolutists dislike libel laws, but it is generally believed that the chilling effect on discourse they exert is balanced by their ability to punish gratuitous false attacks on private individuals. Regulations on the Net need not be any more obnoxious.

The risk, of course, is overreaching—of using law and technology to make the Internet a locus of near absolute control, rather than near absolute freedom. Paradoxically, the myth of unfettered online liberty may help bring this undesirable prospect closer to reality. "Governments are going to set down rules," says [Internet-law specialist Justin] Hughes, "and if you spend all your time fighting the existence of rules you won't have much chance to make sure the rules are good ones."

In other words, hackers may be their own worst enemies. By claiming that the Net is uncontrollable, they are absenting themselves from the process of creating the system that will control it. Having given up any attempt to set the rules, they are allowing the rules to be set for them. Corporations are by no means intrinsically malign, but it is folly to think that their interests will always dovetail with those of the public. The best way to counterbalance Big Money's efforts to shape the Net is through the untidy process of democratic governance—the exact process rejected by those who place their faith in the ability of anonymous hackers to circumvent controls. An important step toward creating the kind of online future we want is to abandon the persistent myth that *information wants to be free*."

Excerpted from "Taming the Web," by Charles C. Mann, first published in the September 2001 issue of Technology Review.

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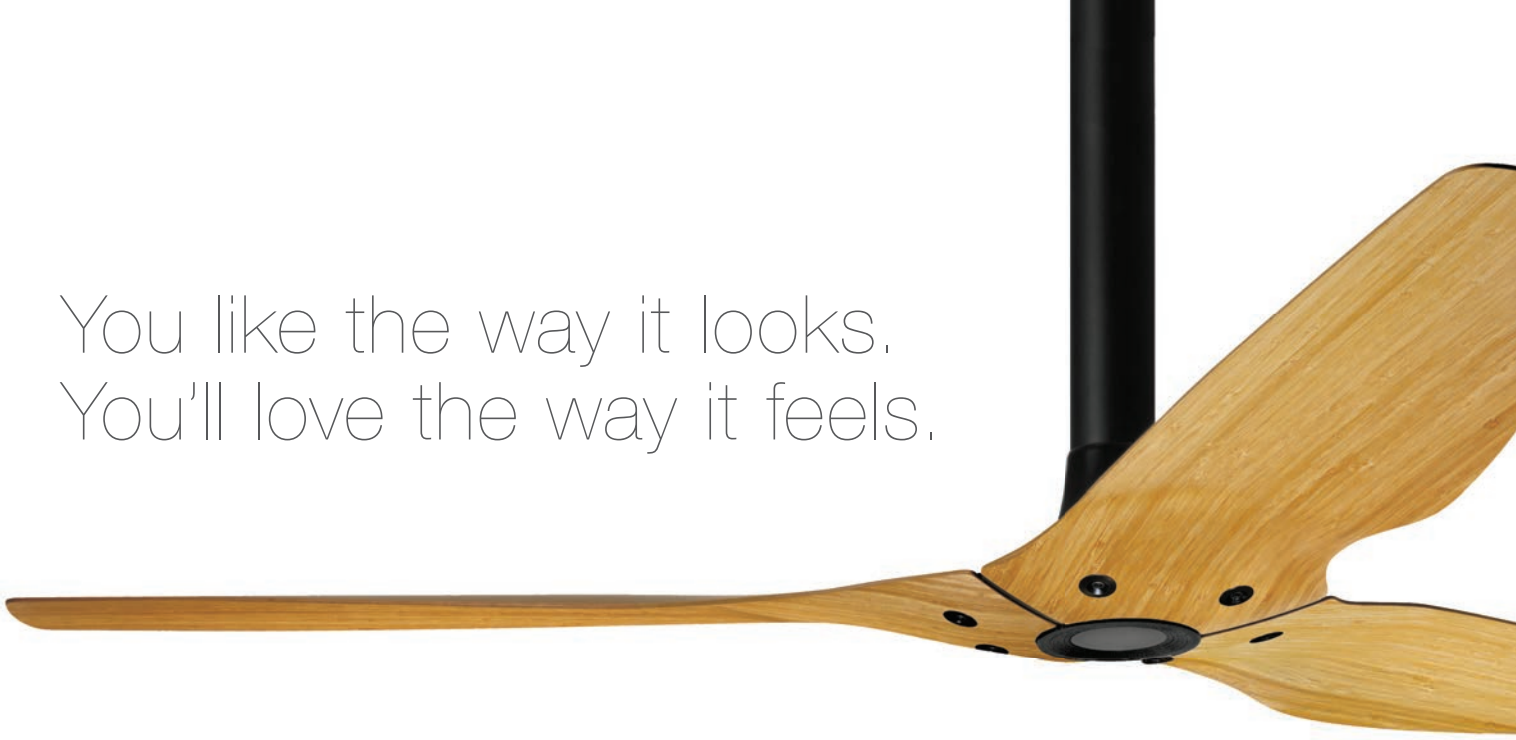

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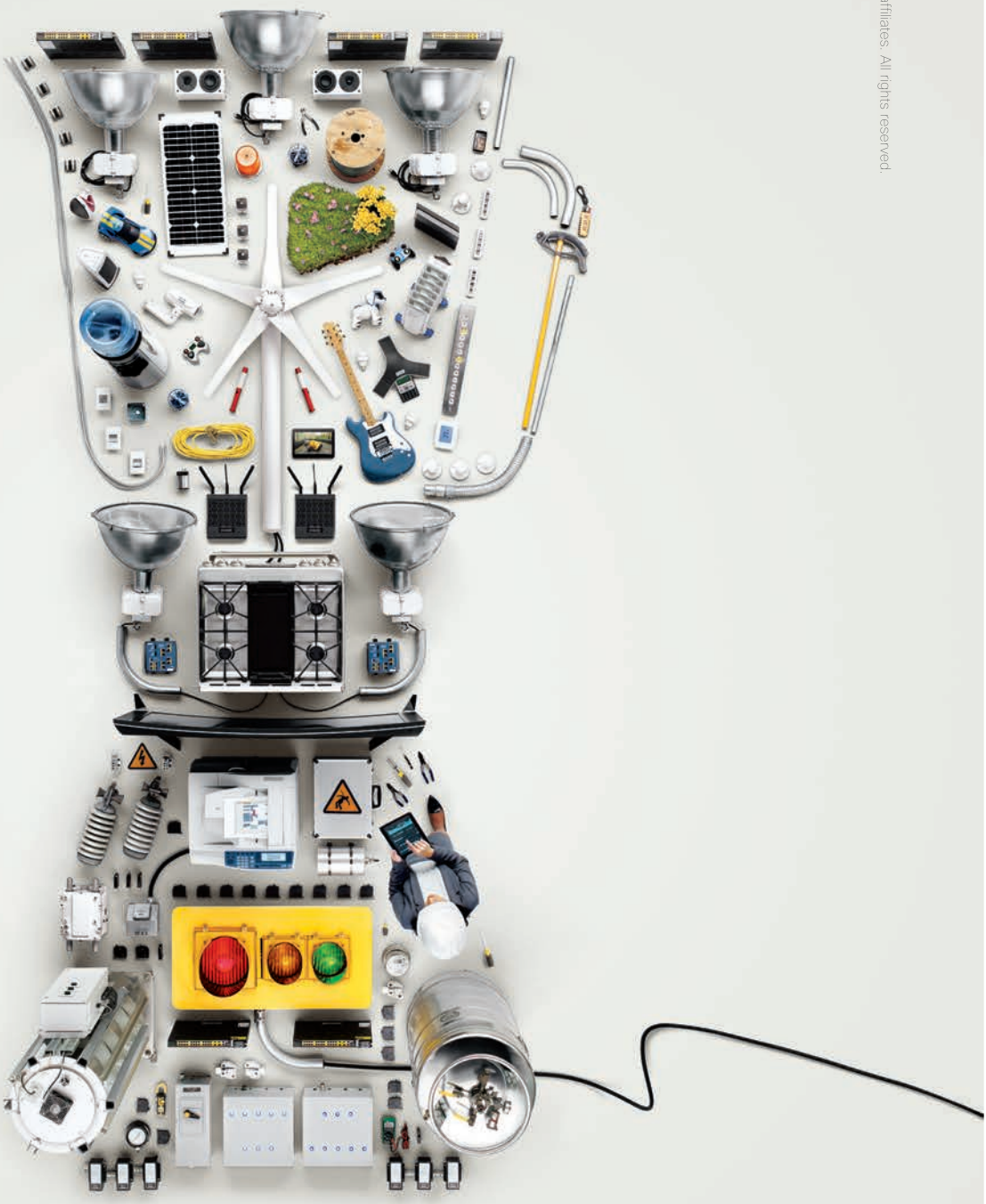

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